INTERMEDIATE BOTANY

BY

M. S. SABHESAN, M.A.,

PROFESSOR OF BOTANY, MADRAS CHRISTIAN COLLEGE.

SPECIMEN

WITH 241 ILLUSTRATIONS

G. SRINIVASACHARI AND SONS

MOUNT ROAD :: :: MADRAS

First Published, 1937

G.S. PRESS
MOUNT ROAD MADRAS

PREFACE

Year after year, intermediate students have been pointing out to the author the difficulty they feel in regard to the study of Botany owing to the lack of a text-book suitable for their use. There are several books written by eminent professors of Botany and they have exerted no little influence on teachers and students all these years. But these books are far above the intermediate standard and they can be used only as books of reference by intermediate students. The author feels that it is necessary to relieve to some extent the strain on students due to the overcrowded curriculum. It is his sincere wish that this **Intermediate Botany** should help students to understand and appreciate better the master-minds of Botany when they proceed to the study of advanced Botany.

Most of the illustrations were specially prepared for this book by Mr. J. D. Chelliah, M.A., B.Sc., L.T., from the materials supplied to intermediate students for practical work in the Madras Christian College. The author is indebted to Dr. M. O. Parthasarathy Aiyangar, M.A., Director, Department of Botany, Madras University and to Mr. K. Ramanathan, B.Sc. (Hon.), M.Sc., for the valuable help rendered by them in respect of the illustrations of algae. The author also wishes to acknowledge the help given by the following gentlemen: Mr. R. V. Narayanaswamy, M.A., L.T., Assistant Professor of Botany, The Presidency College, Mr. Jacob Thomas, M.A., Demonstrator, Madras Christian College, Mr. M. Ananthararaman, M.A., and Mr. Krishnaswamy Sarma.

It appeared desirable to the author to follow some of the oft-repeated diagrams of the earlier botanists, especially in regard to the Cryptogams. While acknowledging his great indebtedness to them, the author should like to state that the diagrams have been modified wherever necessary, solely to suit the needs of intermediate students. Certain details of

structure have been either omitted or represented in a diagrammatic manner so as to avoid confusion.

This book is intended to be an introduction to the study of Botany. The author hopes he can count upon the willing co-operation of his fellow-workers in the field and he will feel grateful to them for any suggestions they may be pleased to offer so as to make the book serve a useful purpose.

MADRAS,
19 May, 1937

M. S. SABHESAN

TABLE OF CONTENTS

CHAPTER I

LIVING THINGS : PLANTS

Living Things. How is it that *living things* are always easily distinguished from *non-living things?* Is there any feature peculiar to living things ? You will say at once that living things breathe, take in food materials, move from place to place, and grow. You may also say that living things are able to reproduce their own kind. Observe any common animal or plant. You will find its body consisting of several parts or organs ; and *organisation* is thus a very common feature of living things.

Plants and Animals. You do not find any difficulty in regarding animals as living things. You may have some doubts about plants. Do not plants respire, take food, grow, and reproduce ? It may be that they do not usually move from place to place like animals. Look at the flowers of the Lotus plant, or the leaves of the Rain-tree. You will find that plants can have their organs moved in space. It is clear therefore that plants are also living things like animals. The work of living organisms, such as breathing, feeding and so on is carried on by different organs. Generally, a definite function is assigned to each organ. The activities may be more or less the same in the two groups of living things but there is a great difference in the way in which the functions are performed. Animals differ from plants in the form and structure of the body and also in their mode of life. Most of the plants show a *green pigment* in the parts of the body exposed to the sun and this is undoubtedly a striking difference between animals and plants.

Organisation of the Plant-body. Pull up a common herb in the field. You will see a long axis running vertically in the centre and forming the axis of the *plant-body.* This body is divided into two different parts. The lower part which grows down into the soil is the *Root* and the upper part grow-

ing up above the soil is the *Shoot*. The part of the axis belonging to the shoot is called the *Stem* and this carries at inter-

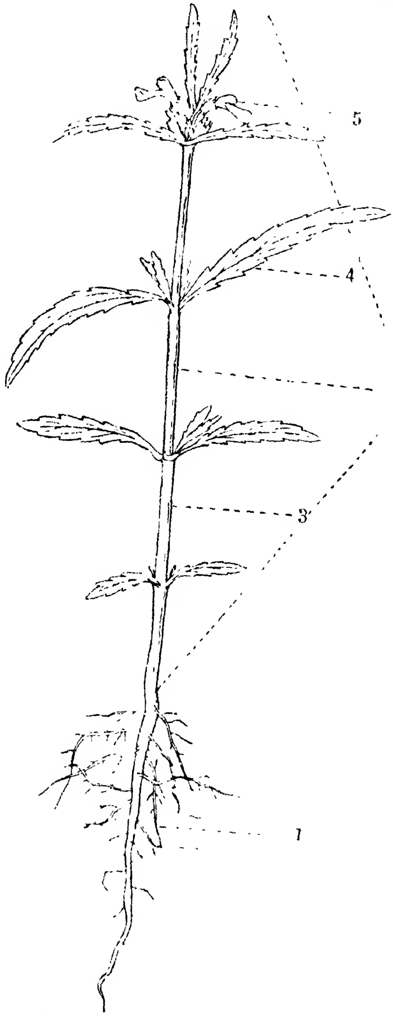


Fig. 1. Leucas : 1. Root-system ; 2. Shoot-system ; 3. Internode ; 4. Leaf at the node ; 5. Flowers.

vals on its sides a large number of green *leaves*. Many of the plants also produce in the flowering season a number of *flowers*

on the stem. It is not all plants that can produce flowers. Plants which bear flowers are, for convenience, described as *flowering plants.* Several plants there are, however, which do not produce flowers at all. These are known as *flowerless plants.* Flowering plants are very common and their body consists of the *Root,* the *Stem,* the *Leaf* and the *Flower.* These are considered as the organs of the flowering plant and they are distinguished from one another by their form, structure and development.

Why, What and How. You will certainly be interested in the study of plant-life ; and the science that deals with it is known as *Botany.* Plants are living things and they show a wide range of variations in size, form and structure. They can be studied from different points of view. For instance, you may be curious to know all about the form of the plant-body. The study of plants from the point of view of general form and structure is called *Morphology.* You may be deeply interested in the work of plants as living things and the study of plants from this standpoint is known as *Plant-Physiology.* You can get a clear idea of the functions performed by plant-organs only when you understand their internal structure. The study of the internal structure in a general way is called *Anatomy* and it will be found necessary to know the details of internal structure. The study of the minute internal structure is termed *Histology* and the aid of the microscope is needed for this purpose. Observe the plants on the way carefully and compare them with one another. Can plants be related to one another ? Try to arrange them according to their resemblance. The arrangement of plants into groups based on their resemblance forms *Classification.* Plants thus present a many-sided interest for you. You are likely to come across flowering plants more frequently and you will do well to begin with the detailed study of the organisation of the flowering plant.

CHAPTER II

THE ROOT SYSTEM

General features. The root is the part of the plant growing beneath the soil. It is shut out from sunlight and covered with the particles of the soil. It appears brown or white and there is no trace of green pigment anywhere on the root. It grows downwards in the direction of gravity and shows a

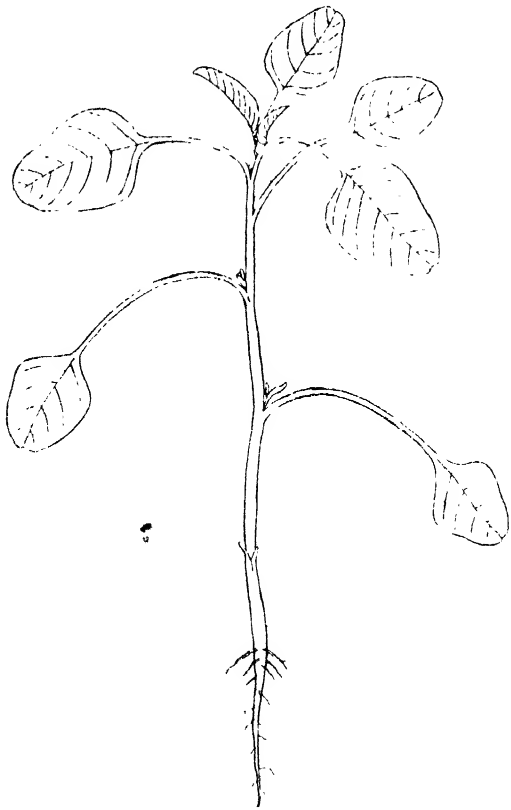


Fig. 2. Amarantus.

tendency to avoid sunlight even when it happens to be exposed to the sun. It tapers finely towards the free end which is directed towards the centre of the earth.

Development. Examine the root of *Leucas* or *Amarantus* carefully. You see in the root-system a central thick axis which forms the direct downward continuation of the central axis of the plant-body. This central root is the chief root and it is called the *primary root* or *tap-root.* This is the first part to come out when the seed is sown. It then gradually develops into the compact root-system. The tap-root is growing exactly vertically downwards and it produces on its sides a large number of smaller roots. These are called *Secondary roots* or *rootlets.* They are thinner and shorter than the tap-root and are arranged in rows along the root. These secondary roots carry, in their turn, on their sides still finer rootlets and this tendency may be repeated. The root-system is thus found to be a much branched region spreading far and wide in the soil. The main root and the numerous rootlets resemble one another in form and structure though they may differ in size. They are all brown with a tendency to taper to a point. While the tap-root grows exactly vertically downwards, the rootlets are inclined and the older rootlets are more or less horizontal. The free end of the root is known as the *root-tip* and it represents the most important part of the root. The root continues to grow owing to the activity of the tip which has to bear the brunt of the soil. There is a need for a protective sheath at the tip and in many plants such a sheath or cap can be seen in the form of a *Root-cap.* The root-cap may be distinct in certain plants while, in several cases, it can be seen only when a section is cut and examined under the microscope. The root-

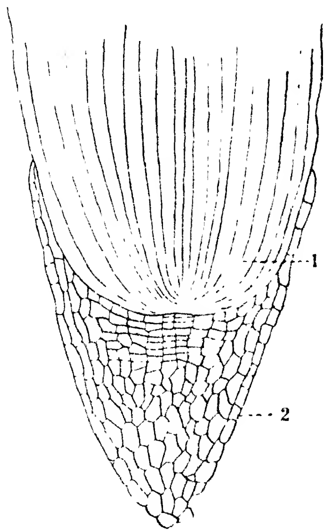


Fig. 3. Root-Tip.
1. Tip : 2. Root-cap.

cap is formed by the activity of the tip itself and it fits over the tip like a thimble. When the root-cap is worn out, it is

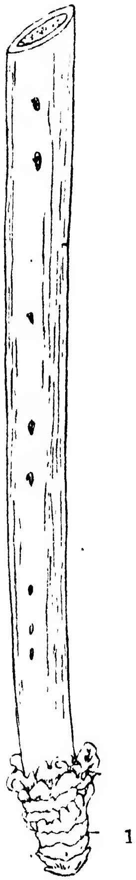


Fig. 4. Pandanus :
1. Root-cap.

Fig. 5. Water-Hyacinth :
a. Root-pocket ; b. Inflated bladder.

renewed from within. The presence of a prominent root-cap-like structure (*Root-pocket* as it is called) in aquatic plants like the Water-Hyacinth is noteworthy but the purpose in such cases is not obvious. There is one other important structure found on the root a little behind the tip. This structure is in the nature of minute soft hairs

which are confined only to the short young zone behind the tip. These hairs are known as *Root-hairs* which occur closely crowded together. When the plant is pulled up, the root-hairs are destroyed. If a young seedling be gently taken out

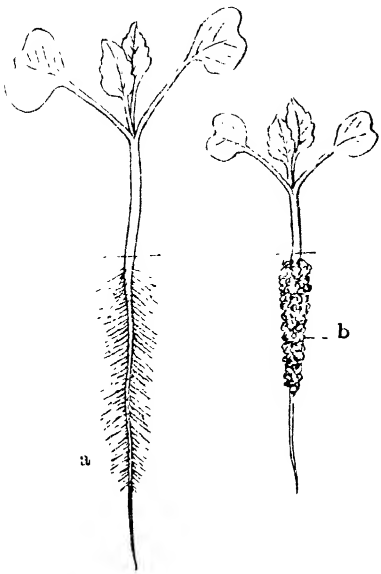


Fig. 6. Root-hairs :
a. Seedling with root-hairs.
b. Root-hairs attached to sand particles.

Fig. 7. Epidermis of the Root :
1. Root-hairs.

and washed, the root-hairs can be seen easily. These are mere minute prolongations of the skin or epidermis of the root at certain points and they are closely associated with the particles of the soil. The older parts of the root are free from root-hairs.

Rootlet. Examine carefully the point at which a rootlet is produced. You will find the rootlet coming out through making a slit on the mother root. Cut the axis crosswise and examine the part with a lens. You will find the rootlet takes its origin from very near the central region of the mother root. The rudiment of the rootlet which originates in the centre has to make its way through the outer layers and to come out

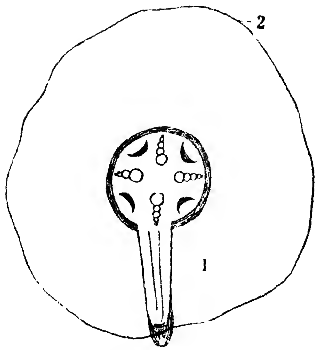


Fig. 8. Origin of the rootlet : 1. Rootlet ; 2. Chief root.

by splitting the skin. Owing to their origin in the central part, the rootlets are described as *endogenous.* They are of various sizes and the older ones may be thick while the younger ones may be very fine and small. All of them, big or small, thick or thin, are endogenous ; and they carry just behind their respective tips, as mere protuberances of the skin, several root-hairs.

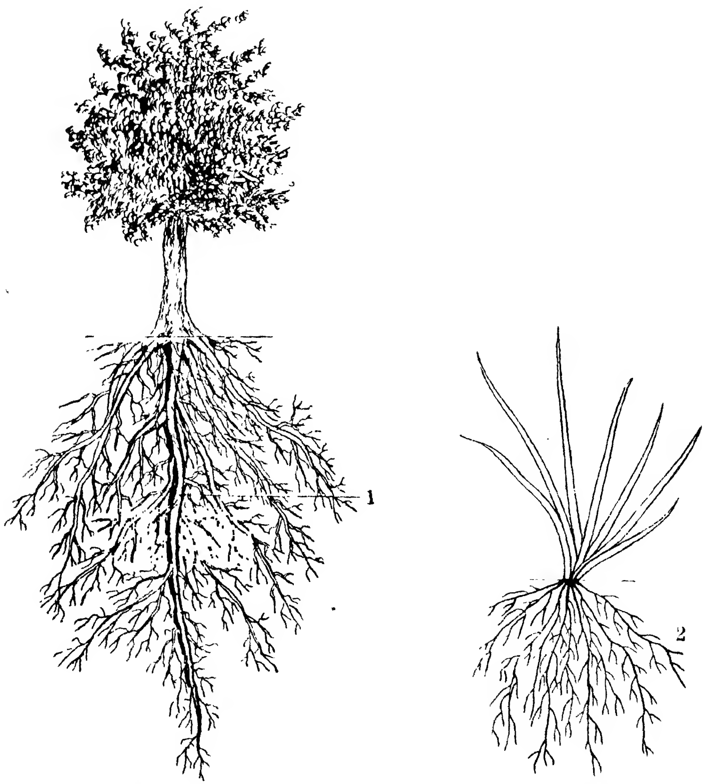


Fig. 9. Root-system : 1. Deep-rooted form ; 2. Fibrous roots of a grass-like plant.

Adventitious roots. The normal root-system is represented by the tap-root and its rootlets. As the plant keeps on growing, the tap-root and rootlets become longer and stouter. In addition to the tap-root system, there may be seen roots arising anywhere on the shoot directly and these are independent of the tap-root. Such roots which arise independently on any part of the shoot are called *Adventitious roots*. Plants like *Lippia* creeping on the soil, carry a large number of roots on the stem and these are quite

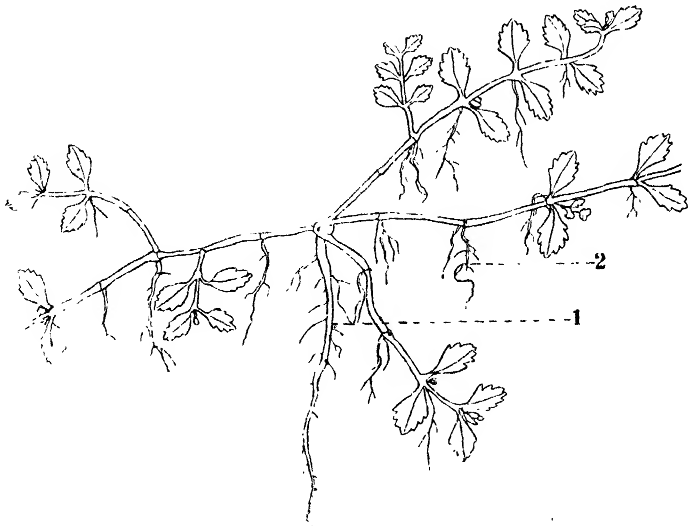


Fig. 10. *Lippia* : 1. Tap-root ; 2. Adventitious roots.

like normal roots. They grow down into the soil, carry rootlets, and serve to anchor the plant to the soil. What about the roots produced by the cuttings of the Croton and the Rose planted by the gardener ? Do not these cuttings develop into new individuals ? The capacity to produce adventitious roots is a valuable one and gardeners take advantage of this. What about the cultivation of the Sugarcane ? In the case of grasses and grass-like plants, the tap-root may cease to be active at an early stage and it may even cease to exist. A number of fine adventitious roots arise in a cluster on the stem and they grow beneath the soil. When roots are slender and

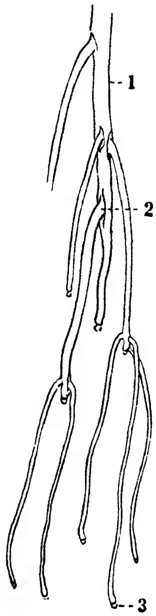


Fig. 11. Aerial Root of the Banyan: 1. Root; 2. Rootlet coming out; 3. Root-cap.

thread-like they are described as *fibrous roots.* Adventitious roots may also in certain cases as in the Banyan tree, arise on the branches of the shoot high up in air. They appear as slender brown roots on the shaded side of branches and grow downwards like an ordinary root. By the time the aerial roots reach the soil, they become very stout and these columnar roots are useful as valuable props supporting the tree. (Have you seen the Banyan tree in the Theosophical Society Headquarters, Adyar ?)

Functions of the root. The root serves to fix the plant firmly to the soil and also to absorb water and other materials from it. The development of the root is generally such as to enable it to do this two-fold work efficiently. The repeated branching of the root makes it easy for the small rootlets to grow through the narrow spaces between the particles in the soil and the plant thus becomes better fixed. A plant whose root penetrates deeply into the soil cannot be easily uprooted. There is another advantage to the plant in having a much branched root-system. It is able to exploit as large a volume of the soil as possible and hence it can count upon an unfailing supply of water. The presence of numerous root-hairs in the young regions of roots increases the efficiency of the root system still further since they are intimately associated with the particles of the soil. They are able not only to fix the plant still more firmly to the soil but also to absorb water and salts surrounding the particles of the soil. The way in which the two functions are performed by the root will be dealt with in detail in a later chapter.

Modifications of the root. The normal root, whether belonging to the tap-root system or to the adventitious type, is seen to taper towards the free end and to carry a large number of rootlets. In certain cases this normal form may be changed

and the transformation may be slight or great. If the change be great, it will be difficult to find out easily its real nature. Any root whose normal form is altered to any extent is called a " modified root " and there are several modifications of the root. It is interesting to see that the modified root has very often a special purpose to serve. Thus, special work may be done by the root and the change noticed in the form and structure of the root is to be regarded as an *adaptation*.

(a) A common modification of the root is known as *Tuberous root* or *Root-tuber*. Here, the root shows a tendency to swell up considerably owing to the storage of materials and becomes a fleshy body. It does not become much branched like the normal root. Look at the Radish. The bulk of the conical white fleshy body is the root. Examine it carefully

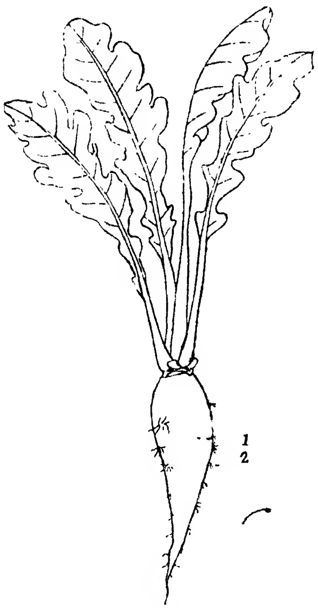


Fig. 12. The Radish : 1. Root-tuber ; 2. Small rootlets

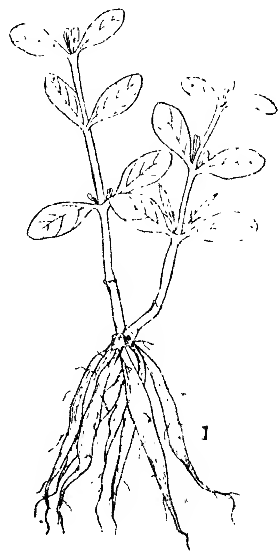


Fig. 13. Ruellia : 1. Root-tubers.

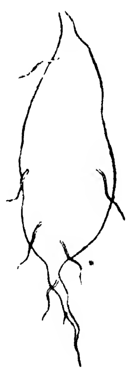


Fig. 14. Sweet Potato : Root-tuber.

and you will find that the tuberous root is really the tap-root of the plant. The root-nature can be recognised by the ab-

sence of the green pigment and by the tapering of the free end. Notice the small clusters of short rootlets produced in two rows on the tuber and see how they split open the skin on coming out. The food-materials stored up in the root-tuber are utilised when the plant begins to produce flowers in the flowering season. Dig up the tuber when flowers are appearing and notice the tuber. Why is it not fleshy now. What about the Carrot and the Beet ? There are other plants like the Sweet Potato which also possess root-tubers. The Sweet Potato plant is a creeper and the stem produces adventitious roots at intervals which swell up into tubers. Root-tubers are very useful to the plant as store-houses of food materials. But there is nothing to prevent man from taking advantage of this provision.

(b) Another modification is the *Stilt-Root.* This type of root is developed in plants where the shoot is rather top-heavy.

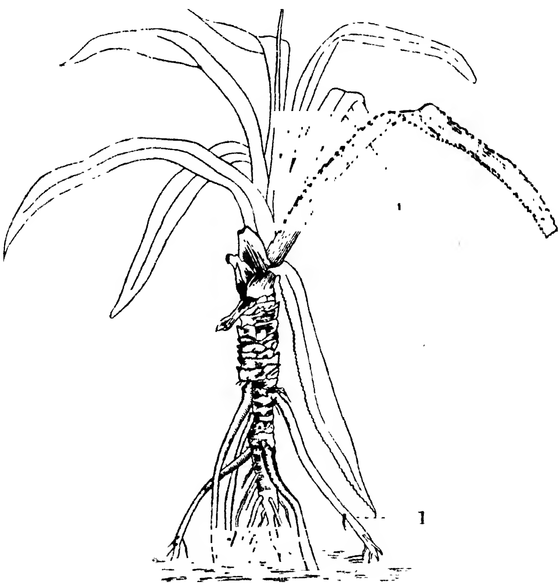


Fig. 15. Pandanus : 1. Stilt-roots.

The slender shoot appears to be mounted on a number of roots which arise close together on the stem and afterwards reach

the soil. These look like stilts and are therefore called *Stilt-roots.* They are strong and are able to keep the plant in position. Such roots are well seen in *Pandanus.* This plant with a top-heavy shoot occurs in marshy or swampy places and it requires strong supports. Numerous stout aerial roots are produced on the stem and those towards the lower portion of the shoot reach the soil and serve as supports. Notice the prominent root-cap consisting of a number of thin brown membranes arranged one inside the other. The Cholam plant whose stem is by no means thick is well supported by a number of stilt-roots springing from the lower portion of the stem.

(c) The modification of the root into a *breathing apparatus* is very interesting. In *Jussiaea* which floats in stagnant

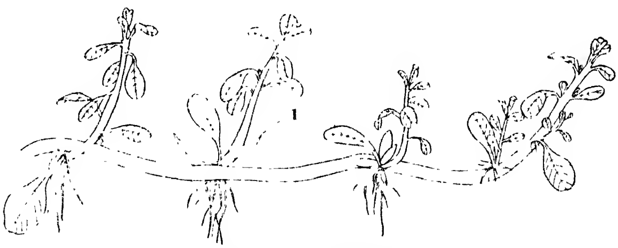


Fig. 16. Jussiaea : 1. Breathing roots.

or slowly moving water, the adventitious roots are produced in clusters at intervals on the stem. These are soft and several of them grow into long and twisted roots. But a good number develop into short, white, spongy, and inflated structures with air-cavities. These spongy bladder-like bodies are really roots which facilitate the exchange of gases. They are therefore to be regarded as special breathing roots which may also help the plant to float in water. In plants growing in swampy regions which are poor in oxygen, the problem of aeration is difficult and some of the roots become specialised into breathing roots. *Avicennia* is a common plant growing on the banks of the Cooum and the Adyar in Madras and a large number of roots of this plant grow up against gravity. They project far above the surface of the soil and show numerous air-cavities inside. They are regarded as efficient breathing roots.

Fig. 17. Avicennia with roots projecting.

SUMMARY

The root forms the subterranean part of the plant. It is a much branched tough structure in the case of land plants and the development of root-hairs in large numbers is a common feature.

In the case of plants floating in water, the roots occur in clusters and they are soft and white. They do not branch repeatedly nor do they possess root-hairs.

Adventitious roots are not uncommon and they are useful in various ways. The aerial roots are sparingly branched and they show no root-hairs.

The root serves to fix the plant to the soil and to absorb water and salts from it. It may become specialised in certain cases and may thus help the plant to thrive well even in unfavourable situations.

CHAPTER III

THE SHOOT SYSTEM: THE STEM

General features. The shoot is green and is therefore more prominent than the root. It grows up against gravity and prefers sunlight. Its growth is healthy only when it is exposed to the sun. The free end of the shoot is called its *apex* and this is directed away from the centre of the earth.

Development. The shoot has, in the centre, a thick axis which forms the upward continuation of the axis of the plant-body. This axis is called the *stem*. When the plant is very young, the shoot is very simple with only a simple axis or stem

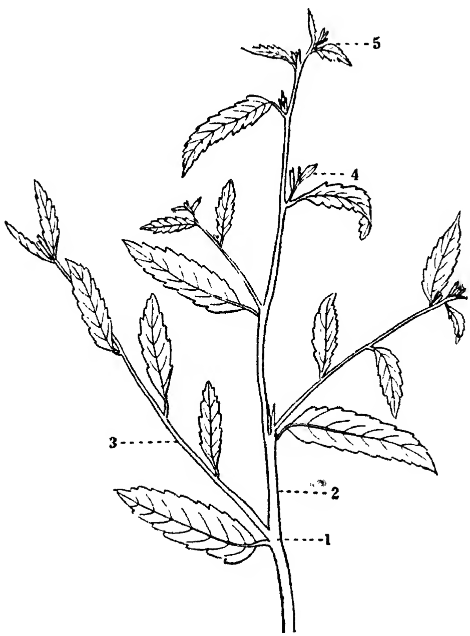


Fig. 18. Main Shoot of Sida: 1. Node; 2. Stem; 3. Branch shoot; 4. Axillary bud developing; 5. Terminal bud.

in the centre. The stem is seen to be slightly bulging at intervals and at these points one or more green leaves are produced.

The bulging part of the stem from which leaves arise, is called the *node*. The stem is thus divided into a number of segments owing to the insertion of leaves at intervals and the portion of the stem between any two successive nodes is called the *internode*. The leaves lower down are larger and older than those near the apex. The differentiation of the stem into nodes and internodes is a characteristic feature of the shoot and the presence of one or more leaves at the node forms still another important feature. Wherever a leaf is attached to the stem, two angles are formed at the point of insertion and the upper angle is called the *axil*. The leaves become smaller as you go up and the internodes also become very short. Look at the apex of the stem. Here is to be seen a tender cluster of rudiments of leaves closely packed together on the terminal point of the axis. This cluster is really a *bud* and on account of its position at the apex, it is called *apical* or *terminal bud*. Every shoot ends in a bud which forms a very important part of the shoot. Here rudiments of new leaves continue to arise and the growth of the shoot is chiefly due to the activity of the terminal bud.

In course of time, the simple shoot becomes much branched and you can see some smaller shoots on the main shoot. These smaller shoots are *branch shoots* and these arise always on **the sides of the stem in the axils of leaves.** The branches are thus lateral and axillary in position and this relationship in position is very interesting. If you observe the plant day after day, you will see fresh branches making their appearance higher up. How do the branches originate? Examine the axil of a young leaf and note the small rudiment there. If you examine it under the lens, you will see a cluster of leaves closely crowded together on a point. This rudiment is really a bud and it is exactly like the terminal bud. This bud is called an *axillary bud* on account of its position in the axil of the leaf and at least one bud is found in the axil of each leaf. You can find that the tiny axillary bud which makes its appearance in the axil of the young leaf develops gradually into a leafy branch shoot. The axillary buds which form the starting point of branch shoots are themselves produced by the terminal

bud along with the rudiment of the leaf. The branch shoots grow side by side with the main shoot and each branch has a bud at its apex. The branch shoots produce smaller branches in the axils of the leaves on their stems and thus the shoot becomes much branched on the whole. The main shoot and the branch shoots are constructed on the same plan and they differ only in size. The main shoot will grow exactly vertically upwards while the branches are somewhat inclined. The older part of the stem tends to become brown and the main stem is distinctly longer and thicker than the stems of branches. A shoot is always distinguished from a root by the differentiation of its axis into nodes and internodes, by the development of leaves at the nodes, by the presence of buds in the axils and by the presence of a bud at the apex of each shoot.

Descriptive terms. If the stem is cut crosswise, the cut-end will appear in different ways. The stem is described as *terete* if the cut-end be circular as in *Hibiscus*; as *square* if it be square as in *Ruellia*; and as *ribbed* if the cut-end be angular and if it should project at the angles in the form of a rib or ridge as in the Pumpkin.

Outgrowth on the Stem. The surface of the stem is frequently seen to carry a number of small hairy outgrowths. Sometimes the outgrowths may become more marked. The nature of the surface will depend upon the nature of the hairy processes. The stem will be described as *hairy* if hairs be present. If there be no hairs at all, it is described as *glabrous*. The stem is described as (1) *pubescent* if the

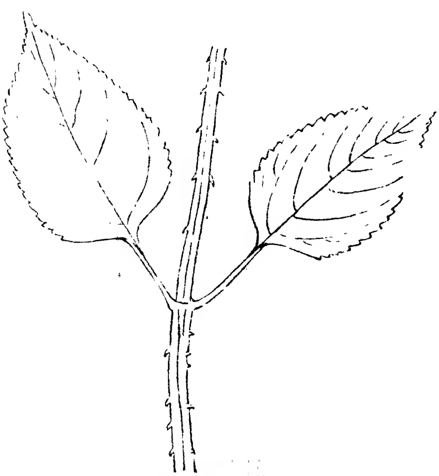


Fig. 19. Lantana.

hairs be short and soft; (2) *stellate* if the hairs should be clearly radiating in the form of stars; (3) *silky* if the hairs be soft; (4) *glandular* if the hairs should secrete a fluid; and (5) *tomentose* if the hairs be brownish white and form a dense covering known as *tomentum* on the surface. The outgrowths present on the stem of the Rose and the Lantana are not of the type of hairs and they are not mere superficial bodies. They are stiff pointed prickles in the formation of which a portion close to the skin of the stem also takes part. These are known as *Emergences* and because they happen to be curved back, they are described as *recurved.* They are in the form of small hooks.

Modifications of the Stem. The normal form of the shoot has been described already. Plants happen to grow in different places and under different conditions. They may not hope to enjoy equally favourable conditions for growth everywhere. It will be a great advantage if plant organs could show a certain degree of adaptability. You have already seen how roots may be modified so as to take upon themselves new functions. The shoots growing in air may also be variously modified and the modification may be partial or complete. The change may begin early in the development of the shoot or at a later stage. Recognition of the stem-nature may become difficult if the transformation be complete or if it should take place at a very early stage. The different modifications of stems enable a plant to get on quite well in different situations and are thus in the nature of adaptations.

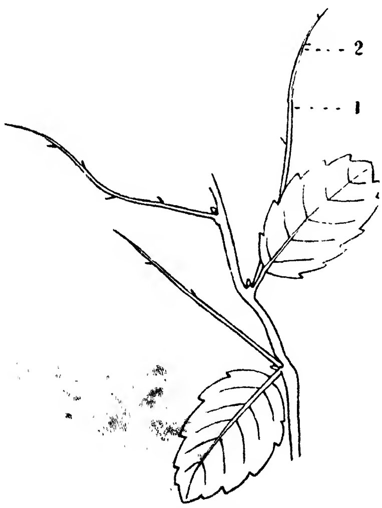


Fig. 20. Gymnosporia : 1. Stem-thorn ; 2. Small leaf.

(1) *Stem-Spine* or *Thorn.* This is a common modification. The spine or thorn is a brown, stiff, pointed structure.

(The difference between a Spine and a Thorn is only a matter of size and the bigger form is known as thorn.) When a stem is modified into a spine or thorn, it is clear that its growth should have been arrested. The arrest in the growth of the stem leads to the formation of the spine or thorn which looks

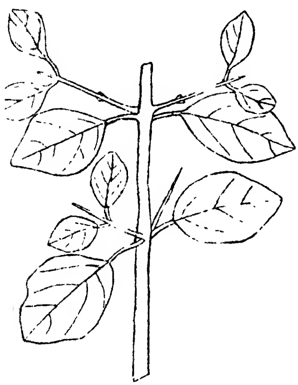


Fig. 21. Gmelina : Stem-thorn.

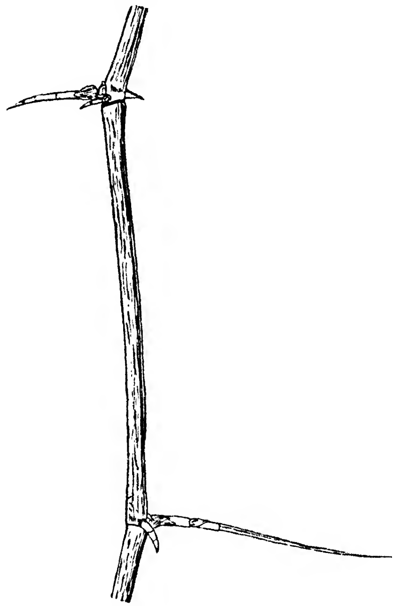


Fig. 22. Stem-thorn in the Bamboo.

like a dead structure. Look at the thorns of *Gymnosporia.* The branched thorns show their stem nature by the differentiation of the axis into nodes and internodes and by the presence of small leaves at the nodes. It is clear that the shoot which has begun to develop into a leafy shoot has become transformed into a thorn. Here, transformation has taken place at a late stage. When transformation takes place very early, the axillary position alone should indicate the shoot-nature. The spines and thorns are the weapons which keep off the grazing animals. In the scrub-jungles of dry districts, plants have to be protected and the thorns are very convenient for the purpose. Can you suggest any other advantage ?

The stem is now in a position to do the work of the leaf. Some other plants there are where the transformation into a flat leaf-like body is not so complete. Even in these plants the leaves are either reduced or they may fall off at an early stage ; and the stem becomes flat and green. The Prickly-Pear,

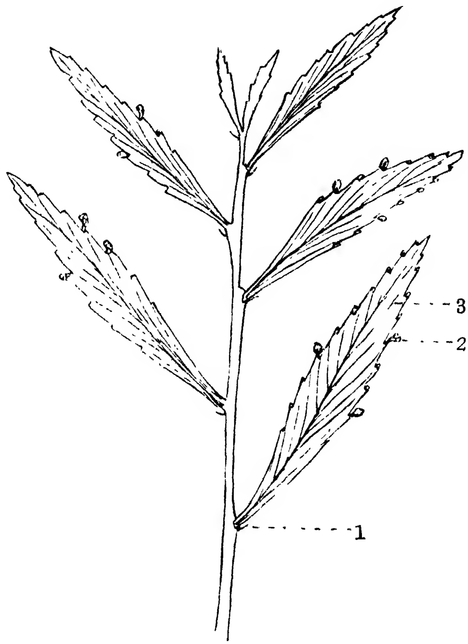


Fig. 25. Xylophylla Cladode.
1. Scale ; 2. Flower ; 3. Cladode.

Opuntia, and the Kalli, *Euphorbia,* are good instances of plants where the leaves fall away early and the stem becomes flat or angular and green. Plants with cladodes grow usually in dry places where the supply of water is limited. Since plants lose water through their leaves in the form of vapour, the presence of a large number of leaves will be a disadvantage in dry places and the above-mentioned plants manage to persist, perhaps because the leaves are dropped. What is the point in the stem becoming flat and green ? The stem in the Prickly-Pear becomes fleshy on account of the storage of

water. A common plant occurring in dry sandy regions is *Casuarina*. Here the needle-like green bodies are really

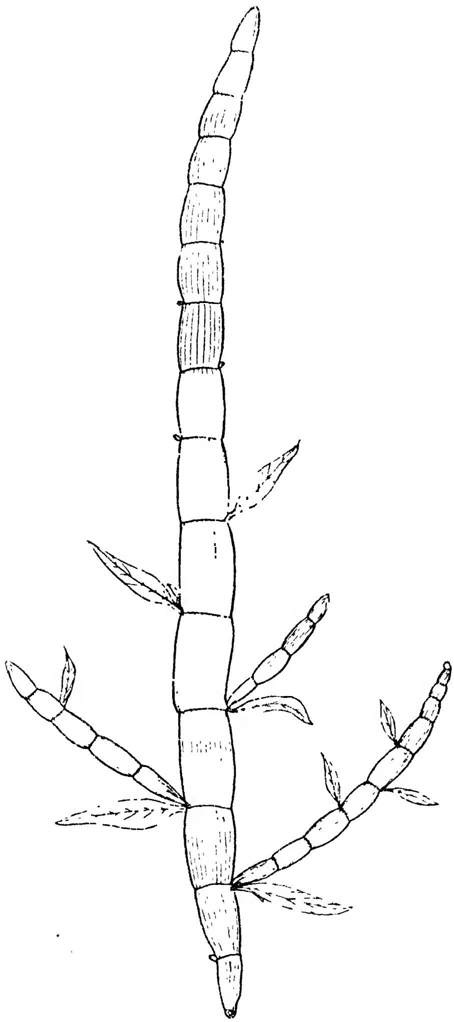


Fig. 26. Muhlenbeckia with flat stems.

branches and the joints represent the nodes. The leaves are reduced to minute brown membranes and the green needle-like shoots carry on the work of the leaf. Since it shows no

tendency towards flattening, the Casuarina shoot cannot be considered as a typical cladode.

Branching of the shoot. The branching of the shoot is very common and the appearance of the shoot will be determined to some extent by the arrangement and growth of branches. There are a few plants like the Palms which do not branch at all. Branches are, as a rule, axillary in position. The rudiment of the branch shoot arises as a protuberance from the outer tissues of the mother axis and the branch need not split the skin to come out. Branch shoots are therefore described as *exogenous*. The branching of the shoot system depends upon the continued activity of the terminal buds. Observe the avenue trees. Many of them have shoots with rounded or umbrella-like tops. There is a stout trunk lower down but higher up the branch shoots appear in twos and threes and they are equally stout. Beyond a certain height, the trunk gives way to a number of branches that present a spread-out appearance. Hence the general appearance is that of an umbrella. You would have heard of the *Coniferous* trees, (Fig. 27) and seen pictures of them. The shoots of these plants go straight up and the main trunk can be recognised right through from the base to the top. The general appearance of the shoot is a cone or pyramid. This is due to the fact that the branch shoots produced lower down on the trunk are longer and stouter while the branch-shoots become shorter as you go up. Hence the broad-based pyramid form is pro-

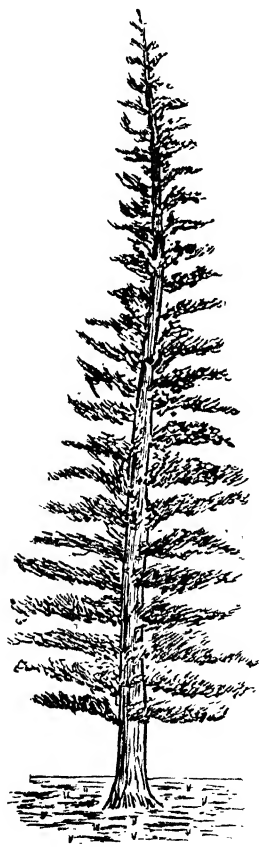


Fig. 27. Monopodial growth.

duced. The difference in appearance seen in shoots is due to one important principle relating to the mode of branching. The growth of the shoot may be divided into two types: (1) *Monopodial,* and (2) *Sympodial.* The monopodial type will show the pyramidal or conical form and will be easily recognised by the presence of the main central axis right through from the base to the top. On account of this peculiarity, trees of this type are described as *excurrent.* This results from the **persistent dominant nature of the terminal bud.** When the terminal bud persists indefinitely and is dominant, the main stem goes on growing and forms the chief central axis. It produces branch shoots in the axils of leaves and the lower branches which have been produced earlier are necessarily longer. The upper shoots will be younger and shorter and the shoot as a whole will naturally appear as a pyramid. Plants with monopodial branching may not be as common as those showing sympodial branching.

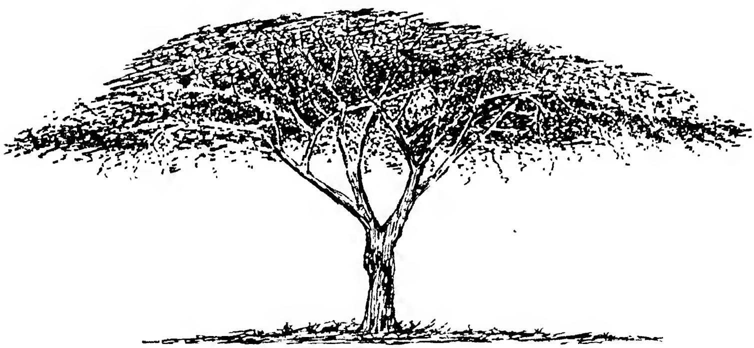


Fig. 28. Acacia : Umbrella-top.

The sympodial branching is easily recognised by the spread-out nature of the shoot. Here, the terminal bud does not persist or it ceases to be active and dominant. When the terminal bud of a shoot dries up or decays or ceases to be dominant, this shoot is not so prominent and the axillary shoot close to the terminal bud will now have a chance of developing vigorously. The terminal bud of the new shoot may in its turn cease to be active and under such conditions

there is no chance for the main axis to persist. The shoot system will be practically made up of successive axillary shoots. It is not possible therefore to recognise a continuous central axis right through; and trees of this type are described as *deliquescent*. This sympodial branching is commonly seen in several plants, especially in trees with rounded, umbrella-shaped or flat tops. The difference in appearance noticed in the shoots of plants with sympodial growth may be due to various minor causes.

Let us study a simple case of sympodial branching. Take the shoot of *Cissus* or *Piper*. There is a jointed central axis which produces one leaf at each node. Opposite to the leaf

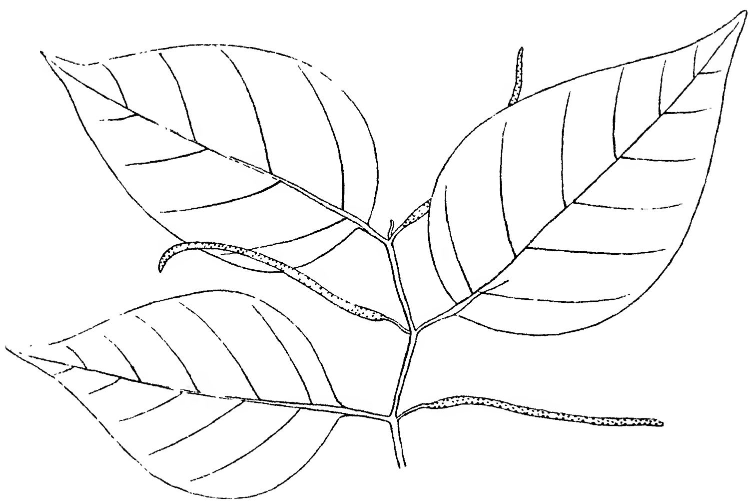


Fig. 29. Piper.

on the other side of the axis is placed a flowering shoot with flowers. In *Cissus*, a tendril with a rudimentary leaf on it may be found instead of the flowering shoot. The flowering shoot which is apparently placed on the sides of the jointed axis is smaller than the axis and may, therefore, be taken for a branch. If it were really a branch shoot, it should be subtended by a leaf since a branch can arise only in the axil of a leaf. There is no leaf subtending the flowering shoot.

If this flowering shoot be not a branch-shoot, it should be the terminal portion of the shoot. In the plants mentioned above, the terminal bud has ceased to be dominant when it develops into a flowering shoot. The axillary bud found in the axil of the leaf close to the terminal bud has a chance and it begins to grow very vigorously into a leafy shoot. The vigorous growth of the axillary shoot results in throwing into the background the terminal bud which is developing into the flowering shoot. This new axillary shoot grows for a time, produces a leaf, and a bud in the axil of the leaf ; and then the terminal portion of this shoot becomes a flowering shoot in its turn as before. Here then, each joint represents the activity of an axillary bud ; and what looks like a continuous central axis is not the result of the growth of the original terminal bud. It is really due to the growing together of the axes formed by successive axillary buds. Hence the name *sympodial branching* (union of several feet) is very appropriate. In *Cissus* and *Piper* the loss of the dominant nature of buds occurs at regular intervals and on each occasion, only one axillary bud begins to develop into a single branch shoot. As the result of growth a single jointed continuous axis is produced. Whenever a shoot is placed opposite to a leaf and not in its axil, the branching should be taken to be *sympodial*. Even the tendril which appears in *Cissus* opposite to the leaf, should be regarded as the modification of the terminal portion of the shoot. In the case of deliquescent trees which present a forked or spread-out appearance, the cessation of the activity of the terminal bud does not take place at such regular intervals as in *Cissus* and a number of axillary shoots begin to develop in different directions when the main shoot ceases to be dominant. The shoot presents a spread-out appearance, but the sympodial nature is still obvious since the main axis is not continued right through.

Habit of the Shoot. Plants are referred to in common language as *herbs*, *shrubs* and *trees*. These terms convey certain definite ideas about the plant. A herb is a small tender plant which does not grow far above the soil and it dies generally within one year. The shrub grows to a height of

about five or six feet as in the Pomegranate, and the stem is strong and woody. It carries several branches from very near the base and lives for some years. Trees are characterised by the development of a stout trunk which may continue to increase in girth. The trunk of trees is very strong, and the timber is of great economic value. They live for years and there are instances of trees which have lived to hundreds of years.

(1) *Erect habit.* The common habit of the shoot is to grow erect in air. This erect growth is noticed in trees, and in several herbs and shrubs. The stems of plants that grow erect should be strong enough to bear the increasing burden of branches with leaves, flowers and fruits. In shrubs and trees, the stem is found to develop hard wood which gives the necessary strength. Timber is valued in building construction on account of the strength of the wood. In the case of herbs, the wood is not so well developed and the stem owes its rigidity to a certain extent to the presence of water in its living cells. Pull up a herb and keep it for a time on the table. It will begin to limp owing to the loss of water. The erect growth is very advantageous since it enables the shoot to make a good display of the leaves.

(2) *Creeping habit.* Several plants there are which possess weak stems. These plants cannot grow erect by themselves since the stem is found to be weak. Plants with weak stems are known as *weak-stemmed plants* and they adopt different methods in order to get the benefit of air and light.

(i) *Prostrate form.* Some weak-stemmed plants are of a humble type and their shoots lie flat on the surface of the soil. Such plants are known as *prostrate plants.* Examine *Tribulus* occurring in open waste places. Notice the long and stout tap-root beneath the soil and also observe the numerous shoots arising in a tuft close to the soil and lying flat on the surface. The weak shoots are supported by the earth.

(ii) *Creeping form.* Another kind of weak-stemmed plant is the *creeper.* (Fig. 10). You have this type in *Lippia* which grows in moist places. The general habit is more or less the same as that of the prostrate plant, but the shoots are

far longer. A special feature of the creeper is its capacity to produce adventitious roots at the nodes. These develop vigor-

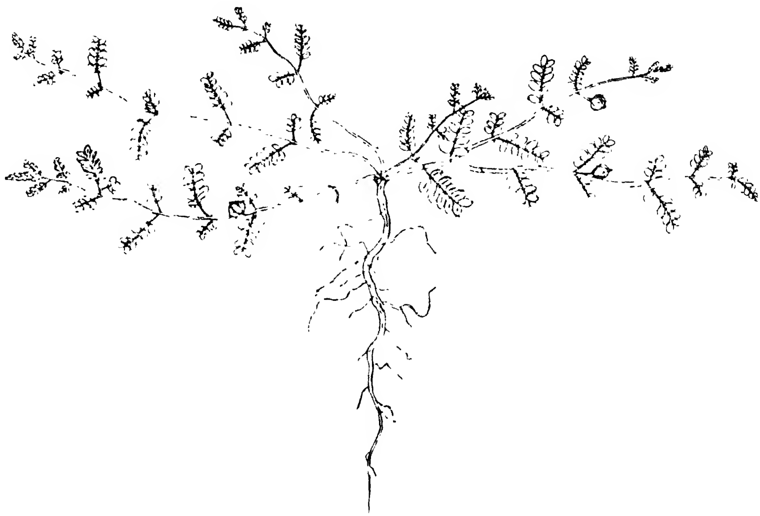


Fig. 30. Tribulus : Prostrate form.

ously, grow into the soil and become much branched. The numerous roots and rootlets form a net-work inside the soil and besides fixing the creeper firmly to the soil, they are able to bind the loose particles of the soil. Such creeping plants as *Lippia* and *Ipomaea* are efficient sand-binders and

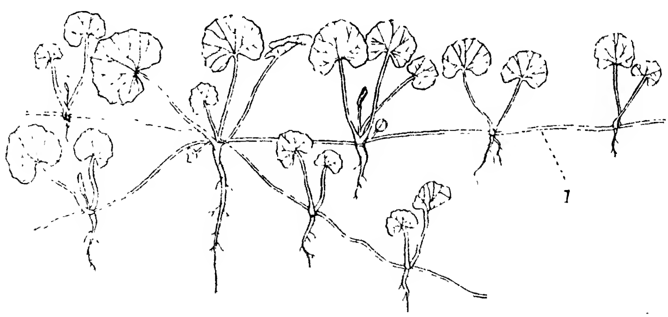


Fig. 31. Centella : 1. Runner.

they are usually grown to keep the tank bund firm. If the stem of a creeper should happen to be cut, each bit can easily

grow into an independent individual. Is this not a convenient method for the multiplication of plants ?

(iii) *Running form.* A very interesting form is the *Runner* which is typically developed in *Centella,* common in all wet places. Runner is the name given to the fine slender axis which arises from the axil of a leaf and extends rapidly over the surface of the soil. The free end of the runner strikes root and the terminal bud develops into a shoot with a short tuft of leaves. From the axil of each of the leaves of the new shoot, another runner will be given and this too will develop in a similar manner. This runner-habit is a device to help the plant to spread itself rapidly over a region.

(3) *Climbing habit.* This habit is noticed among a better type of weak-stemmed plants. They manage to climb up by clinging to strong supports. Their growth is not appreciable if they do not find close by a suitable support to which they can cling. There are a few general characteristics worth noticing in climbing plants. The stem is generally string-like and the internodes are very long. Very often the leaves are in no hurry to develop and, besides remaining rudimentary for a long time, they are seen to be closely pressed to the stem. Hence the stem looks like a long whip and it is easy for such a stem to make its way through little gaps without let or hindrance. What is the disadvantage if the leaf should develop early and stand out ? There are different kinds of climbers.

(i) *Twiner.* The Back-yard Bean, *Dolichos,* is a common plant. On coming out of the seed, the shoot grows erect for a time. Very soon it shows the need for a support. You may have seen people fixing a number of twigs close by. The weak whip-like stem is revolving in air and it may, in the course of these revolutions, come across the support. Since the stem continues to revolve, it forms a number of spiral coils round the support. Owing to this twining peculiarity, the climber is known as *twiner.* The free end of the twiner is free to revolve further and the coils of the spiral get closer. The twining stem has a firm grip on the support and the weak plant may grow up with the help of the support. Here, no

specialised organ is developed for the sake of twining and the stem itself has, in addition to its normal work, to twine round the support. Unless the support is more or less vertical, it will not be possible for the stem to twine. In course of time, the twiner may become very woody in some cases and such strong woody twiners are developed in forests. When the twiner has managed to climb up, the leaves begin to unfold. Now is the time for the display of leaves. In the case of certain twiners, special hairs or brown corky protuberances are also developed which prevent them from sliding down the support.

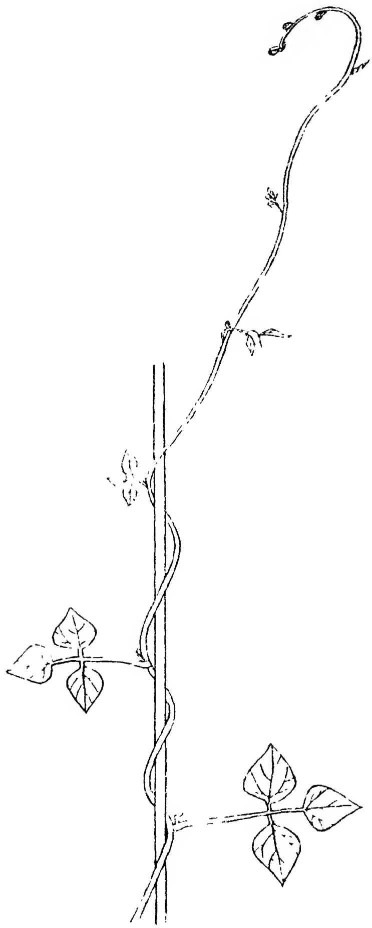


Fig. 32. Dolichos lao-lab.

(ii) *Tendril-Climber.* You have already learnt something about the tendril. It is useful as a clinging organ. It is at first slender and straight and the tip is easily irritated when coming into contact with a rough surface. It also revolves of its own accord in air and its tip may rub against the rough surface of a support. When the tip is irritated, it forms a number of close coils round the support. Thus the weak-stemmed plant is brought close to the support and the tendril has clung to it. The body of the tendril which has not come into contact

Fig. 33. Clitoria : A Twiner.

with the support is thrown into a number of spiral coils and this coiling which is a special feature of the tendril has a mechanical advantage. When the wind blows, the tendril both of whose ends happen to be now fixed, does not break since the coiling of the tendril makes it act as a spring. A to and fro movement is thus possible and it is an interesting thing to notice that the coiling of the body of the tendril does not proceed in the same direction. As a matter of fact, the direction is reversed at equal intervals for mechanical reasons. There are numerous tendrils developed all along and these are efficient clinging organs. A tendril-climber is therefore

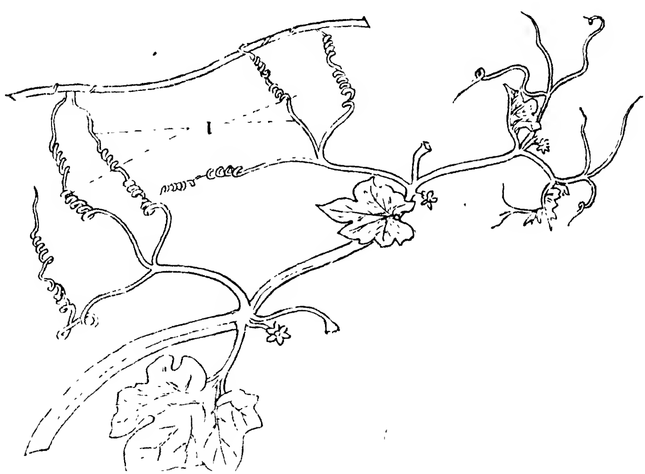


Fig. 34. Trichosanthes : 1. Tendrils.

much better placed than a twiner. *Cissus* and *Passiflora* have already been mentioned as possessing tendrils which are modifications of stems. You will see later on how other plant-organs may also be modified into tendrils. Whatever part the tendril may represent, (Fig. 35) it is always a good clinging organ.

(iii) *Watch-spring climber.* In plants like *Bauhinia*, strong hook-like structures are seen on the stem near the axil

of the leaf. They are at first straight but their tip becomes gently curved on coming into contact with the support. Then the tip forms a few coils round the support like a tendril and

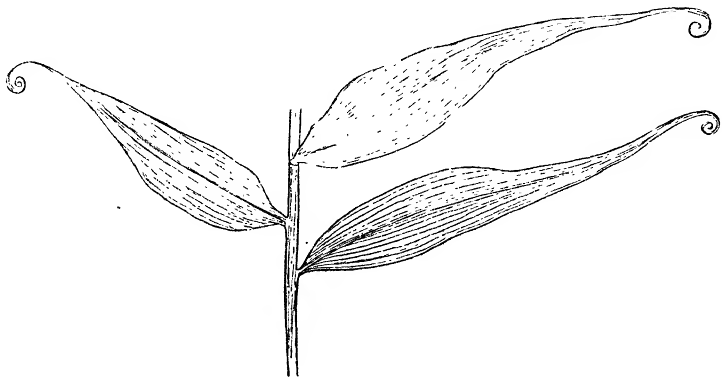


Fig. 35. Gloriosa : Leaf-Tendril climber.

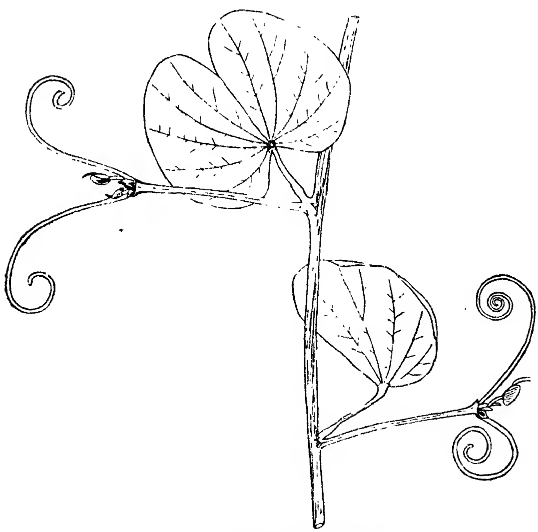


Fig. 36. Bauhinia.

gets a firm grip. Hence these hooks may be regarded as special tendrils though the body is not coiling. These tendrils become in course of time strong and woody.

(iv) *Root-climber.* Aerial roots may also be employed as clinging organs. A good instance is the Pepper plant. A cluster of short aerial roots is given at the nodes on the shaded side of the stem and these grow in the crevices of the bark of the supporting branch and begin to spread there. They are thus able to fix the weak Pepper plant to the support. In the Botanical Gardens, you may see several big root-climbers. *Philodendron* produces numerous roots on the shaded side and these are in such close connection with the support that it is found difficult to pull out the plant. There is a root-climber called *Ficus repens* which resembles the Ivy. The short roots

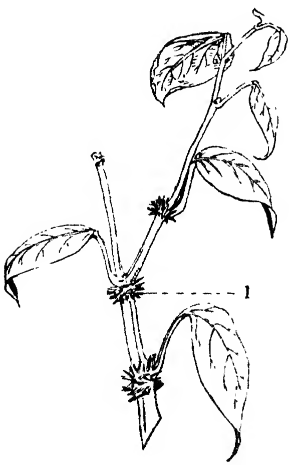


Fig. 37. Piper.
1. Root.

Fig. 38. Solanum.

secrete a gummy fluid which makes the plant stick to the support.

(v) *Hook-climber.* This is a group of climbers known also as *Scramblers.* These possess small prickly hooks which hold on to supports and thus keep the weak-stemmed plant in position. The indifferent type of scramblers is represented by *Solanum* and the Rose. Here the hooks are numerous and they are in the nature of emergences. Since they are recurved they are in the form of hooks and can cling to supports. A more efficient type is represented by *Capparis* where a part of the leaf is modified into a recurved hook. Scramblers spread rapidly on the hedges and they are a nuisance. Mention should be made of *Asparagus,* a common scrambler in the scrub-jungle (Fig. 70). Here the lower half of the leaf is modified into a thorn which acts as a convenient clinging organ.

With so many devices for climbing, it is no wonder that climbing plants are able to hold their own. They are able to place their leaves in a favourable position ; and their leaves

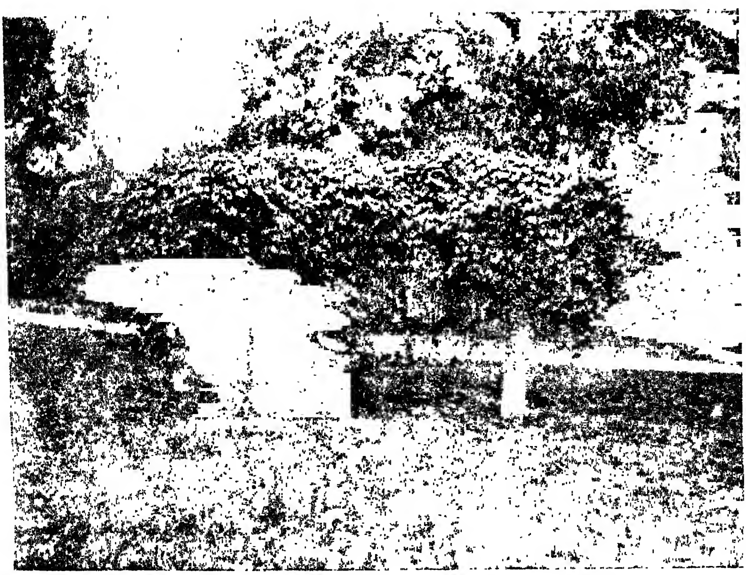


Fig. 39. Display of leaves.

and flowers may be seen to occur all over the crown of the supporting tree. In forests, exposure to sunlight becomes a seri-

ous problem owing to the dense growth of large trees and it is strange that the climbers are seen at their best in forests. This is not a little due to the devices seen in plants for climbing.

(4) *Subterranean* or *underground habit.* The subterranean or underground habit is really an interesting one. It is found that the shoot-system is able to grow beneath the soil in certain plants. Conditions in the soil are altogether different and it is natural that a subterranean stem should differ very much from a normal aerial shoot. The entire shoot-system is not found beneath the soil in any plant. In plants with subterranean shoots, there is always a portion of the shoot which is above the soil and grows in air and light. You have thus got in these plants, *subterranean shoots* and *aerial shoots* side by side and the difference between the two is very striking. Since the subterranean shoot is shut out from sunlight, the stem and the leaves show no green pigment and are brown like the root. The stem which is easily mistaken for a brown root shows the usual differentiation into nodes and internodes and its nature is easily recognised. Fur-

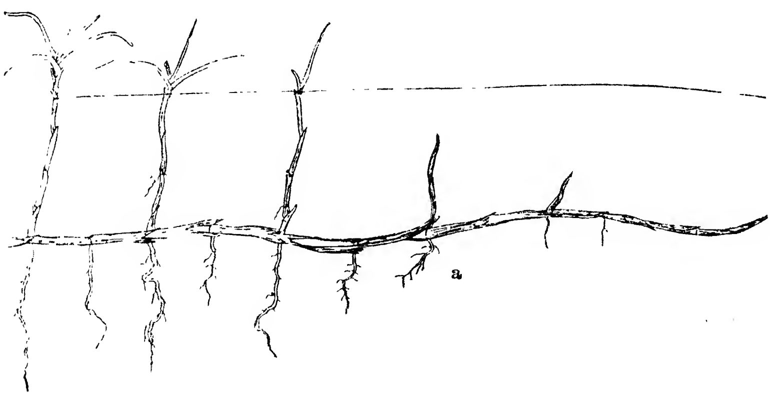


Fig. 40. Cyperus arenarius : a. Rhizome.

ther, the brown stem carries leaves at the node but these leaves are very much reduced. Their growth is arrested and they appear as brown thin membranes, known as *scales*. Buds also are found in the axils of these scales and there is a bud at the apex. The subterranean shoot is really a shoot but it is modified owing to its position beneath the soil. Usually the sub-

terranean stem stores up food-materials and becomes fleshy. Some of the buds develop into shoots which grow up and come out into the open air. These are to be called *aerial shoots* in opposition to the subterranean shoot. These aerial shoots are like normal shoots and show well-developed green leaves. Observe the plants with subterranean shoots throughout the year. You will find the aerial shoots drying up and decaying in the dry summer in the tropics or in cold winter in temperate regions. When the season becomes unfavourable for activity, the aerial shoots die and disappear. The subterranean shoots, however, remain unaffected beneath the soil. The entire activity of the plant is suspended for the time being but the subterranean shoot is alive. As soon as the season turns favourable, the buds on the subterranean shoot make use of the water and other food materials contained in the shoot and begin to develop more or less simultaneously. Thus there is a sudden awakening of life and this is made possible by the subterranean habit. The subterranean shoot is a good device to tide over adverse seasons and it becomes easy for plants having such a shoot to live in a place for years together. The development of buds into shoots is greatly helped by the supply of materials from the subterranean shoot which serves as a store-house. Man will not be slow to take advantage of this feature in plants. He makes use of several subterranean shoots for his food and goes one step further. He employs these shoots for the purpose of propagation. When portions of the subterranean shoot containing a few buds are cut and planted, there will be produced new individuals. They can thus be used for propagation instead of seeds. Propagation by means of the ordinary organs like the root, the stem and the leaf is known as *Vegetative propagation.* The subterranean shoots assume different forms.

(i) *Rhizome.* This is the name given to the axis of the subterranean shoot which is fairly long and continues to grow horizontally in the soil. As it grows, it gives rise to adventitious roots at the nodes by means of which the rhizome is fixed to the soil. At the node is to be seen a leaf which is modified into a thin brown membrane called the scale. Axillary buds present in the axil of the scale either develop

into branch subterranean shoots or into aerial green shoots. *Cyperus arenarius* which is common in the beach shows all these features very clearly but the underground stem is thin. Ginger and Turmeric which you see in your houses are really subterranean shoots in which you can see the sheathing scales and buds. But the stem is rather short and it becomes fleshy owing to the storage of materials. A bit of Ginger or Turmeric will, if planted separately, grow into a new individual and hence the rhizome will be useful for vegetative propagation.

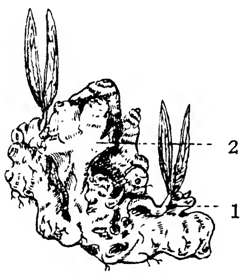


Fig. 41. Ginger.
1. Aerial shoot.
2. Rhizome.

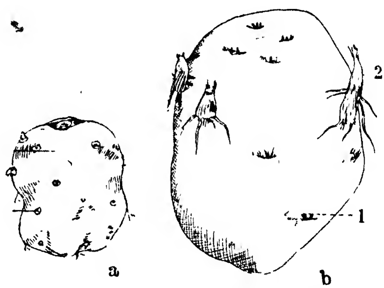


Fig. 42. Potato tuber :
a. Tuber with small buds ;
b. Tuber : 1. bud, 2. bud developing into a shoot.

(ii) *Stem-Tuber*. When a subterranean shoot ceases to grow in length but tends to grow in bulk, it becomes a massive fleshy structure and is called a stem-tuber to distinguish it from a root-tuber. This tuber also stores up plenty of materials to be utilised by the buds when they begin to develop. The common Potato is a stem-tuber. A number of small shoots arise from the normal shoot of the Potato plant, but begin to grow in the soil. Thus these small branches become subterranean shoots and they begin to swell up at the free end owing to the storage of materials, the lower slender part attaching the tubers to the stem. Tubers are often found in clusters. The potato is spherical and appears pitted. Observe the pits carefully and you can recognise in them small buds known as *eyes*. The scales placed close to the pits are very minute. Cut a potato into a few bits and plant them

separately. The buds in the pits will become visible and they develop into shoots at the expense of the materials in the tuber.

(iii) *Corm.* A third modification of the subterranean shoot is the corm which is well seen in the wild and cultivated forms of *Amorphophallus.* The main stem of the Chena (a cultivated form) is subterranean and it becomes swollen into a huge mass. A big bud is left near the depressed top-part. When the Corm is placed in the soil, the bud

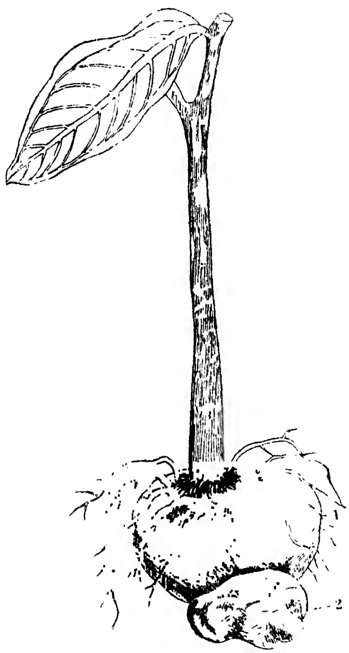


Fig. 43. A wild form of Amorphophallus : 1. New corm ; 2. Old corm.

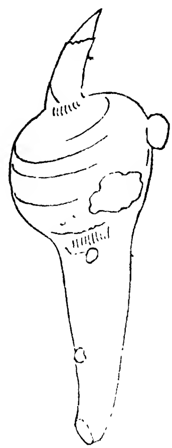


Fig. 44. Colocasia.

will begin to develop at the expense of the materials stored up in the corm and begin to strike root. As the shoot is growing, the old corm becomes considerably reduced and finally a new individual is produced with a short subterranean stem sending out a green leaf. The materials prepared by the leaf are passed on to this stem which in its turn grows into a huge

corm. The subterranean shoot of *Colocasia* which is commonly used in our houses is a tuber or corm which is slightly elongated.

(iv) *Bulb*. The Onion and the Garlic represent the type of subterranean shoot known as the bulb. The part in the soil is a fleshy bud-like structure from which a few green leaves

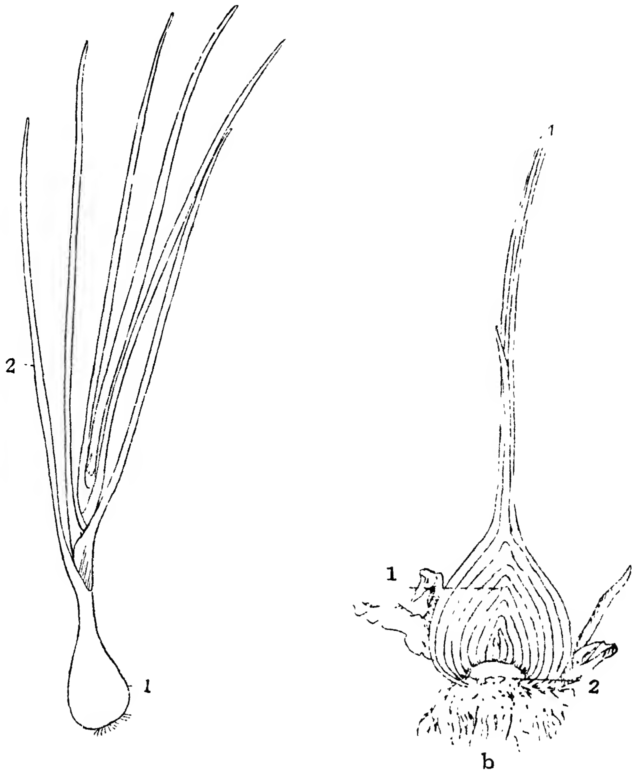


Fig. 45. The Onion : a. Onion plant : 1. Bulb, 2. Leaf ; b. The Onion in L. S. : 1. Scales, 2. Subterranean stem.

come up above the soil. Cut the bulb region lengthwise and examine. You will see a reduced brownish disc-like structure at the bottom and this is really the subterranean stem. It produces from the lower surface a cluster of short adventitious roots and on the upper surface arise a number of sheathing juicy scales packed together and arranged one

inside the other. The outer scales are thin and they are clearly seen to be the sheathing bases of leaves. The inner ones are very fleshy and are modified leaves. A peculiar thing in the Onion type is the insignificant nature of the underground stem as against the prominent fleshy scales. In the flowering season the disc-shaped stem sends out a flowering shoot. The bud-like subterranean shoot is called a bulb and it differs from other forms of underground shoots in having a reduced stem with thick juicy leaves. The bulb of the Onion and Garlic shows scales arranged in concentric circles and they can be removed only one after another.

Duration. Plants are divided roughly into three classes: (1) *Annuals*, (2) *Biennials* and (3) *Perennials* according to their duration. Several herbs live only for one season and they die after the seeds are produced. They complete their life-cycle within the year and their seeds are sent out. Such plants are called Annuals. Most of the herbs are annuals. Biennials are plants whose life-cycle is spread over two different seasons. The Radish is a good example of biennials. In the first season, the root and the leaves are well-developed and the material manufactured by the leaf is stored up in the root which becomes massive. Flowers begin to appear only in the second season and the materials are utilised during the production of flowers. With the formation of seeds the life of the biennial comes to an end. The first season when the root and the shoot are active is known as the *Vegetative season* and the second season marked by the production of flowers is known as the *Reproductive season.*

Perennials are plants that continue to live for several years. In their case, the production of seeds does not result in the death of the individual as in annuals and biennials. In the vegetative season they put forth leaves and in the reproductive or flowering season a large number of flowers are produced. The flowering shoots wither after the seeds are formed but the plant continues to exist as an individual for years. Trees and shrubs are perennials. Even herbs may manage to live for years and produce flowers in the proper season if they happen to possess a subterranean shoot.

Cyperus arenarius may remain in its place for several years. Such herbs are known as perennial herbs.

Functions of the stem. The stem is primarily intended to keep in position a large number of leaves and flowers. It is a supporting organ and is able to bear a heavy burden on account of the development of mechanical tissues like wood. Materials absorbed from the soil have to be transported rapidly to the leaves and the stem is thus also useful as a conducting organ. The branching of the shoot serves to make a good display of the green leaves and flowers.

SUMMARY

The shoot is green, growing up in air and sunlight and the stem is differentiated into nodes and internodes.

The green leaves arise at the nodes and there are numerous buds present, one at the apex of each shoot and at least one in the axil of each leaf.

The shoot growing in air may be variously modified.

The shoot is much branched, the mode of branching being monopodial or sympodial.

The habit of the shoot is varied and the development of special clinging organs is noteworthy.

The subterranean shoot is a remarkable device to tide over the adverse season and it assumes several forms.

Plants may be divided into Annuals, Biennials and Perennials.

CHAPTER IV

THE LEAF

General characteristics. The leaf is a dark green body arising in large numbers on the stem. It forms a very important appendage of the stem and grows well when exposed to the sun. Very few plants can manage to grow in the shade. Sunlight is necessary for the development of the green pigment in the leaf and the work of assimilation can go on in the leaf only with the help of sunlight. The leaf is flat and spread

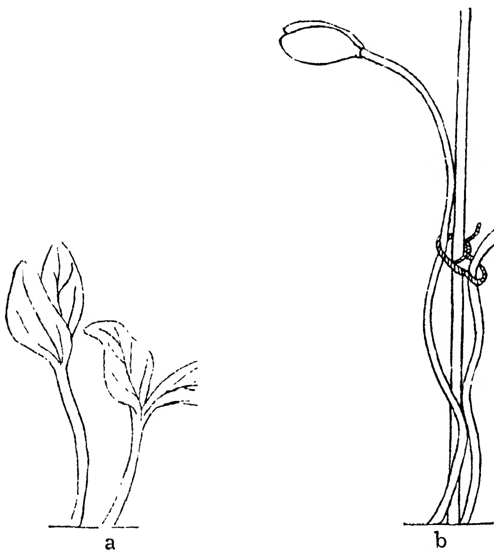


Fig. 46. Plant and Sunlight : a. Growth in sunlight ; b. Growth in darkness.

out and it places itself at right angles to the rays of the sun. Look at the seedlings which are kept in darkness. They will be abnormally elongated and flabby and the stem and the leaves will be yellowish. They are looking unhealthy and will develop green colour only if they be placed in the sun. The unhealthy condition noticed in plants kept in darkness is known as *etiolated condition.*

Development. The leaf arises as a small rudiment at the node of the stem. It may arise singly or in large numbers at

the node. The rudiment very soon becomes differentiated into three parts. The leaf shows a broad, flat, thin green portion known as *Lamina* or *Blade*. This is attached to the node of

Fig. 47. Hibiscus : 1. Lamina ; 2. Petiole ; 3. Stipule.

the stem by a short stalk, called the *leaf-stalk* or *petiole*. At the point of insertion of the leaf are to be seen two greenish leaf-like outgrowths, one on each side of the petiole, and these are known as *stipules*. The blade, the petiole and the pair of stipules form together the leaf. The blade is the most important part and is present in every leaf. The petiole is found in many leaves and it serves to keep the blade in a favourable position. Leaves with petioles are described as *petiolate*. The petiole may sometimes be absent and the leaves which are directly attached to the stem are described as *sessile*. The stipules occur at the node in pairs and they may not be present in all plants. Leaves with stipules are termed *stipulate* while those without stipules are described as *exstipulate*. The leaf grows rapidly and completes its growth in a comparatively short time. You can distinguish one kind of plant from another since each kind shows a leaf type of its own. The

lower edge of the blade is the *base* of the leaf and the free end of the blade is called the *tip*. The petiole is usually attached to the base of the blade. Sometimes it may be

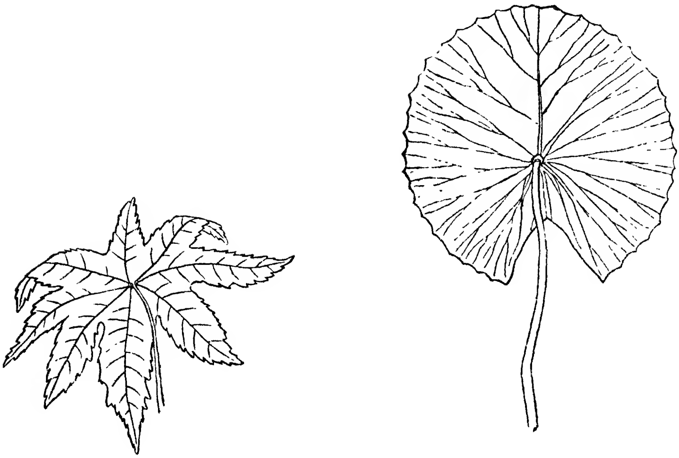


Fig. 48. Peltate leaf : a. The Castor leaf ; b. The Water-Lily.

attached to a point in the under surface of the blade inside the margin, as in the Castor plant and the Water-Lily. The blade is then described as *peltate* or shield-shaped. Many descriptive terms are in use which will help you to give a correct account of the plant. (It is good for you to observe the leaves of plants carefully and describe them in appropriate technical terms.)

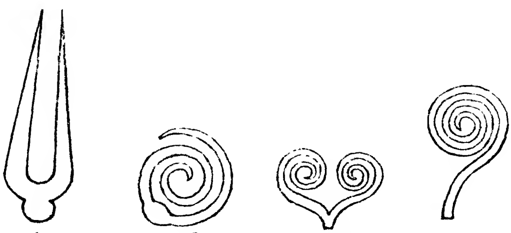


Fig. 49. Vernation : 1. Conduplicate ; 2. Convolute ; 3. Involute ; 4. Circinate.

(a) *Vernation* :—The leaves are seen as small rudiments in the bud and they are folded in different ways on themselves.

Their disposition in the bud is known as *Vernation.* The leaf is described as:

Conduplicate, if the young blade be folded on itself lengthwise along the middle line;

Convolute, if the young blade be rolled into a tubular sheath as in the Plantain from one edge to the other;

Involute, if each of the two halves of the blade be rolled on itself upwards towards the middle line.

Plicate or Plaited, if the young blade be folded lengthwise several times as in the Palms.

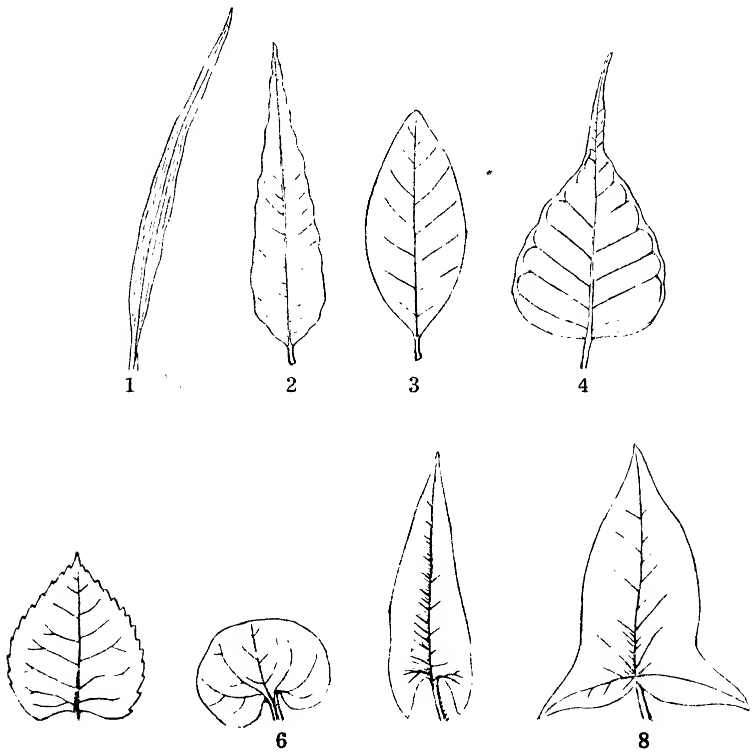


Fig. 50. Forms of the Blade: 1. Linear; 2. Lanceolate; 3. Elliptic; 4. Ovate; 5. Cordate; 6. Reniform; 7. Sagittate; 8. Hastate.

Circinate, if the leaf be rolled in the form of a watch-spring from the tip to the base as in the Ferns.

(b) *Form of the blade* :—The form of the blade is various but generally it is the same in all the individuals of any one kind. Some of the common forms are mentioned below :

Linear (long and narrow like a line).
Lanceolate (like a lance).
Elliptic (broad in the middle and narrow at the two ends).
Oblong (uniformly broad and the ends are not narrow).
Ovate (very broad at the base and narrowed at the tip).
Cordate (like the heart).
Reniform (kidney-shaped).
Ob-lanceolate (narrow at the base and slightly broadening at the tip).
Obovate (narrow at the base but very broad at the tip).
Obcordate (the broad portion of the heart towards the tip).
Rotund (circular).
Sagittate (Arrow-shaped).
Hastate (the two projecting bases spread out).

(c) *The Tip of the Blade* :—The tip also shows different forms. The blade is described as :

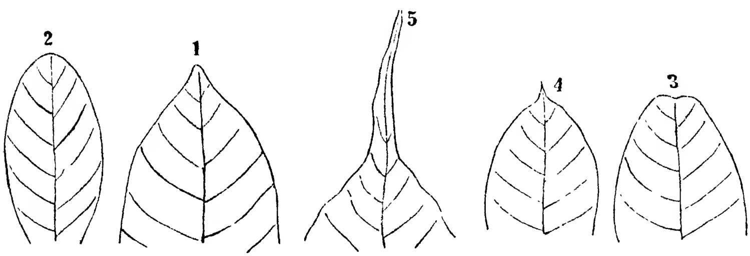


Fig. 51. Tip of the Blade : 1. Acute ; 2. Obtuse ; 3. Emarginate ; 4. Mucronate ; 5. Acuminate.

Acute, if the tip should form an acute angle.
Obtuse, if the tip be more or less blunt.

Emarginate or *Notched,* if a bit of the tip appears to be missing.

Mucronate, if the tip should protrude distinctly.

Acuminate, if the tip be drawn out into a long filament.

(d) *Margin of the Blade* :—The blade is :

Entire, if the margin be an even continuous line ;

Wavy, if the margin be bent up and down or undulating ;

Fig. 52. Margin of the blade : 1. Entire ; 2. Wavy ; 3. Serrate ; 4. Crenate ; 5. Dentate ; 6. Pinnately lobed ; 7. Palmately lobed.

Toothed, if the margin be slightly interrupted so as to present a toothed appearance :

(1) *Serrate,* if the teeth in the margin be sharp and should point to the tip of the blade.

(2) *Crenate,* if the teeth be rounded.

(3) *Dentate,* if the teeth be sharp and should point outwards.

Lobed, if the margin be more deeply cut so as to give the appearance of a number of lobes.

(1) *Palmately lobed,* if the lobes should look like the digits of the palm as in *Jatropha* (7 in Fig. 52).

(2) *Pinnately lobed,* if the lobes be directed to the mid-rib and arranged like the soft downy structures of the feather as in *Solanum* (6 in Fig. 52).

(e) *The Surface of the Leaf* :—The blade may or may not have hairs scattered on its surface. The same terms used to describe the surface of the stem may be employed in the case of the leaf as well.

(f) *Texture of the Leaf* :—The leaf is:

Herbaceous, if the blade be thin and tender.
Leathery, if it be tough and difficult to tear.
Succulent, if it be juicy.
Coriaceous, if it be tough and rigid.
Crustaceous, if it be firm and brittle.

(g) *Venation of the blade* :—The blade is traversed by a large number of rather stiff structures known as ribs. The ribs branch in the blade repeatedly until very fine structures called *veins* and *nerves* are formed. Ribs, veins and nerves all represent together the skeleton of the blade and constitute a framework. The blade is generally divided lengthwise into symmetrical halves by a strong central rib proceeding directly from the top of the petiole. This is known as the *mid-rib.* When the blade is divided into two unequal portions by the mid-rib, it is described as *oblique.* The study of the arrangement of the ribs and their branches in the blade is called *Venation.* The venation of the leaf is of two kinds: (1) The *Parallel* type as in the grasses like the Paddy and the Cholam; and (2) the *Reticulate* or *Net* type as in *Hibiscus* and the Mango.

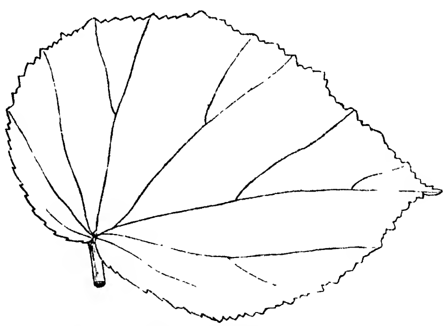


Fig. 53. Begonia. Oblique leaf.

In the leaves of grasses and grass-like plants, a number of more or less similar ribs including the mid-rib enter the

base of the blade and run parallel to one another from the base to the tip. There is no clear branching of the ribs which are

a b

Fig. 54. Parallel venation : a. A grass ; b. Commelina.

apparently free from one another. This venation is therefore called parallel venation and it may be good enough for long and narrow leaves.

The Reticulate Venation is very common and here the ribs branch repeatedly and the veins seem to meet one another so as to form a net-work. In this type of venation every part of the blade is connected with some vein or other. The reticulate venation may occur in two forms :

(1) *Pinnate reticulate* as in *Ficus religiosa* and the Mango and (2) *Palmate reticulate* as in *Thespesia.*

In the pinnate reticulate type, the blade shows only one prominent rib which is the mid-rib. The other ribs are branches springing from the sides of the mid-rib along its course. The arrangement of these branch-ribs on the mid-rib resembles the arrangement of the barbs of the feather. Owing to the repeated branching of the ribs, a net-work is formed. The venation is described as *Pinnate reticulate* because a network is formed as the result of the branching of the ribs which are arranged in a pinnate manner. In the palmate reticulate type, you see more than one prominent rib entering the blade from the petiole

and diverging in the blade. The mid-rib is still prominent but along with it other ribs also enter the blade. The arrangement

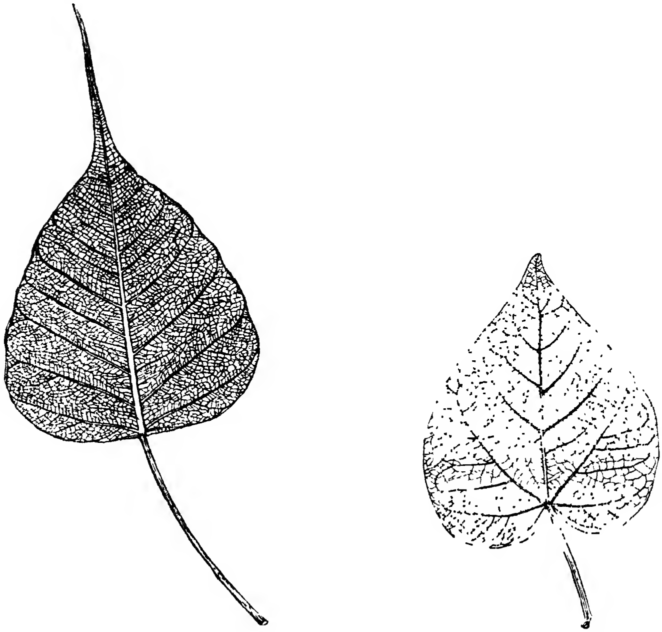


Fig. 55. Reticulate venation : a. Ficus religiosa—Pinnate ; b. Thespesia—Palmate.

of the chief ribs resembles that of the digits of the palm; and these ribs branch repeatedly in the pinnate manner to produce the network. Hence the venation is described as *Palmately reticulate.* The venation of the Plantain leaf is somewhat peculiar. There is a stout mid-rib extending from the base to the tip and this is the only prominent rib. A number of slender branch ribs arise in a pinnate manner but no further branching is noticeable. Consequently no network is formed. Further, the branch ribs are running parallel to one another from the mid-rib to the margin. The Plantain leaf shows a combination of the parallel and pinnate principles in an imperfect manner. The disadvantage of an imperfectly developed type of venation is clearly seen in the Plantain. What happens to this leaf when the wind blows ? The ribs and their branches are intended to serve as the skeleton

of the blade and also to help the transport of materials in the leaf. They have to serve two purposes : (1) A mechanical purpose and (2) a transporting purpose. The parallel venation cannot give a good protection to the blade against wind except in the case of small and narrow leaves. Nor can materials be carried quickly to and fro. A net-work type of venation will prove a better framework and the blades wont be easily torn. Since the veins traverse every nook and corner, a network venation carries materials to every part of the blade and takes away the materials as quickly as possible.

Kinds of leaves. The leaves are divided into two kinds, (1) *Simple leaves* and (2) *Compound leaves.* A simple leaf

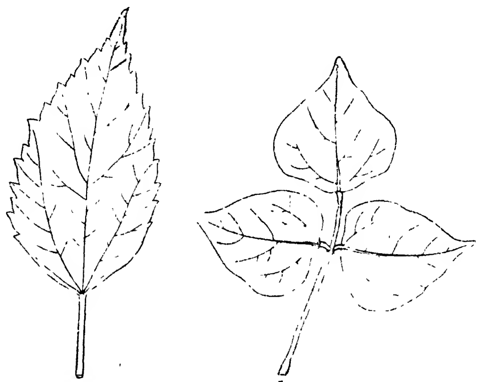


Fig. 56. Kinds of leaves : a. Hibiscus (Simple leaf); b. Dolichos (Compound leaf).

is one where, during the differentiation of the rudiment of the leaf, only one blade is produced. This blade may be entire or lobed, big or small ; and the leaf will be described as a *simple* leaf so long as the petiole carries only one blade, e.g. *Hibiscus*, the Cotton, and the Mango. There are plants like the Margosa and *Dolichos* where several blades are seen to be separately attached to the petiole. Such leaves where you have more than one blade separately attached to the petiole are termed *Compound* leaves. Each of the several blades of a compound leaf is called a *leaflet* for the sake of convenience. The compound leaf is supposed to have been formed as the result of a

tendency for branching on the part of the leaf rudiment. The form of the compound leaf will be determined by the manner and degree of branching of the leaf rudiment at an early stage. If the rudiment should branch repeatedly, the petiole will present a much branched appearance and the leaflets will be

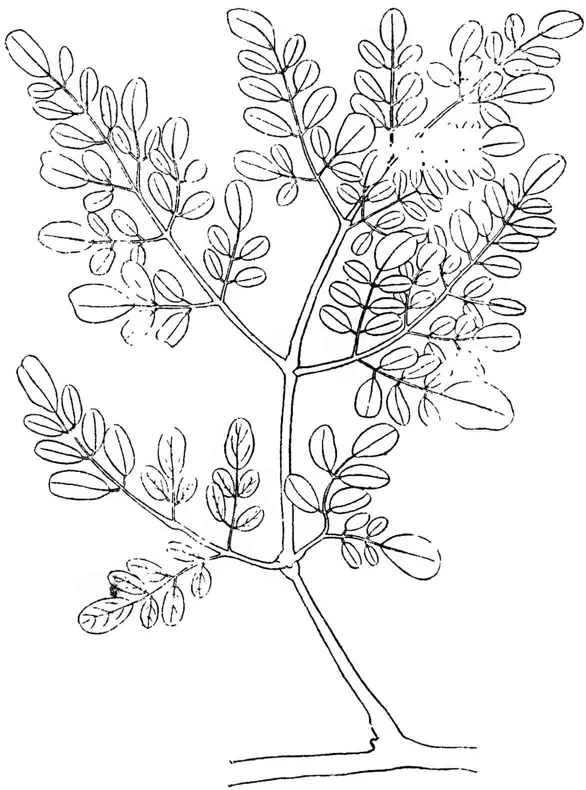


Fig. 57. The Drum-stick Plant : Decompound leaf.

borne not immediately on the petiole itself. Examine the leaf of the Drum-stick plant. Does it not look like a branch shoot with axis and branches ? Yet it is only a leaf because it arises at the node and subtends a bud in its axil and carries no bud at its tip. The numerous small blades are merely the leaflets of one leaf. Imagine the space between the leaflets to be filled

up and you will easily get the idea that the whole thing represents only one blade. The axis-like structure in this compound leaf corresponds to the petiole and the mid-rib ; and it is called *Rachis.* Compound leaves may be either *palmate* or *pinnate*

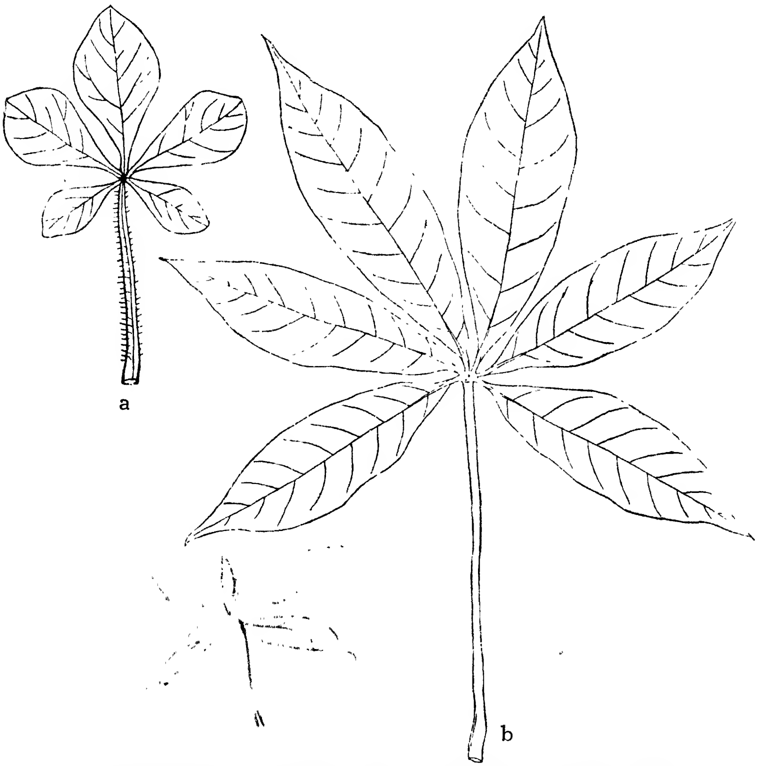


Fig. 58. Palmately compound leaf : a. Cleome ; b. Eriodendron.

according to the arrangement of the leaflets. In a *palmately compound leaf* as in *Cleome* and *Eriodendron*, the leaflets are few in number and they are attached separately to a point on the top of the rachis and their arrangement resembles that of the digits of the palm. The rachis corresponds to the petiole alone in this type. A *pinnately compound leaf*, on the other hand, has got many leaflets which are arranged at intervals all along the rachis and hence the leaf is described as *pinnately compound.* The rachis of a pinnately compound leaf is longer than that of the palmately compound leaf and it represents the

petiole and the mid-rib. The Margosa leaf is described as *imparipinnately* compound leaf since the rachis ends in a

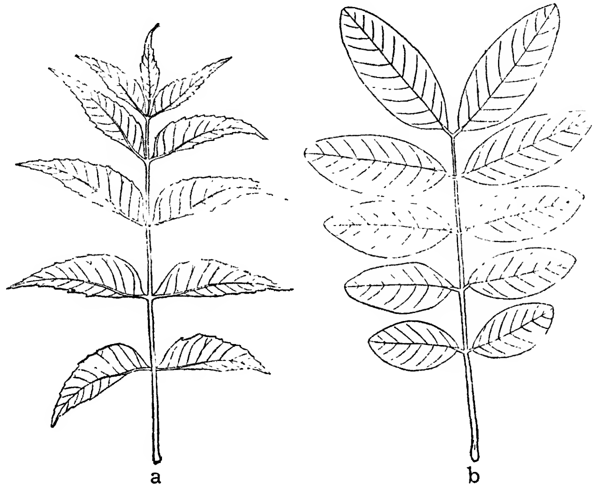


Fig. 59. Pinnately compound leaves : a. Margosa—Imparipinnate ; b. Cassia—Paripinnate.

single leaflet. In the Tamarind or *Cassia*, the rachis ends in a pair of leaflets and such a type of pinnately compound leaf is called *paripinnately* compound leaf. A leaf with three leaflets as in Dolichos is described as *trifoliate* or *ternate.*

The leaf of *Caesalpinia* shows a further branching of the leaf-rudiment and its leaf is different in appearance from that of the Tamarind. There is in the centre of the leaf an axis-like structure, the rachis, and the leaflets are not borne at once on this rachis. You find all along the rachis a number of branch rachises. Hence the central rachis is regarded as the *Primary rachis* and the branch rachises arising from its sides in pairs at intervals are known as *Secondary rachises.* The arrangement of the secondary rachises on the main rachis is of the pinnate type. Each secondary rachis carries numerous small leaflets in pairs and the arrangement of the leaflets on each secondary rachis is again pinnate. The leaf rudiment branches twice and the arrangement of the structures on each occasion follows pinnate type. Hence the leaf is described as *Bi-pinnately compound.* Each secondary

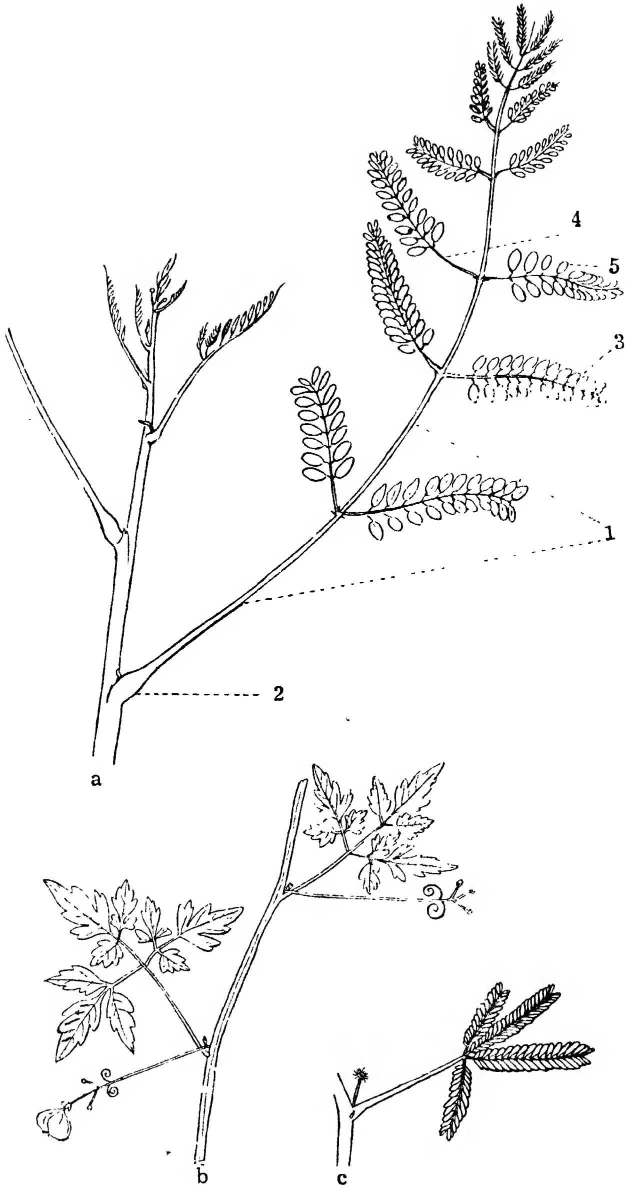


Fig. 60. Bicompound leaves : a. Caesalpinia : 1. Primary rachis ; 2. Pulvinus ; 3. A Pinna ; 4. Secondary rachis ; 5. Leaflet ; b. Cardiospermum ; c. Mimosa.

rachis with the leaflets on it is called a *pinna.* A similar type occurs in *Acacia* as well. Leaves which show a tendency to branch twice are generally called *Bi-compound* leaves and the bi-pinnately compound leaf of *Caesalpinia* represents only one type of bi-compound leaf. Examine the leaf of *Cardiospermum.* You can see a primary rachis which produces three secondary rachises close together. Each of these three secondary rachises carries close together three leaflets. This is again a bi-compound leaf and the arrangement on each occasion may be regarded by some as *palmate* and the whole leaf may be considered as *bi-palmately compound* leaf. Can you show that the so-called bi-palmate leaf of *Cardiospermum* is nothing more than a bi-pinnately compound leaf ? Since the structures arise in threes, it is usual to consider this type as *bi-ternately compound leaf.* The leaf of the Sensitive plant is still another kind of bi-compound leaf. There is a primary rachis which carries a few secondary rachises in a palmate manner but the leaflets are arranged in a pinnate manner on each secondary rachis. Hence the leaf should be described as *palmately pinnately compound.* Study again the leaf of the Drum-stick plant. There is a primary rachis which carries several secondary rachises and these in turn carry finer branch-rachises of different lengths. Branching may be repeated still further and the number of leaflets borne may not be the same on the smaller rachises. This is really an irregular type of multi-pinnately compound leaf described as *decompound.* In all these compound leaves the branching of the rudiment is the underlying principle and whatever may be the size of the compound leaf, it may be easily distinguished from the real shoot since it shows all the characteristics of the leaf.

Arrangement of the leaf. Generally, the axis of the shoot is fairly long and the leaves are separated by distinct intervals. In some plants like the Radish and *Mollugo,* the stem is insignificant and short. Hence the leaves produced by the short stem are found close to the soil and look as if they arise from the root. They are on that account called *Radical leaves* and they are not separated by intervals. But plants usually

possess stems which grow in length and the leaves of such plants which are separated from one another by internodes are known as *Cauline leaves.* The cauline leaves are arranged in one or other of the three ways, (1) *Alternate,* (2) *Opposite,* and (3) *Verticillate* or *Whorled.*

The arrangement of the leaf is alternate if only one leaf be produced at each node as in *Thespesia.* The second leaf is not placed on the same line over the first leaf. If a thread be taken along the stem so as to touch the points of insertion of successive leaves, it will be tracing a spiral and hence the

Fig. 61. Mollugo.

alternate arrangement is also called *Spiral arrangement.* Since the leaves appear to be arranged in no regular order, this arrangement is also termed *scattered.* It is not correct to say that the leaves are not arranged in a regular order. Take any shoot with alternate arrangement and start with any leaf. Find out which upper leaf is exactly on the same line over the leaf which formed your starting point, and count the number

of leaves passed over by you. Mark this leaf placed on the same line over the first leaf and proceed further up to find out the leaf which is exactly on the same line above this. The number of leaves passed over now is the same as that passed over on the first occasion. The same number of leaves will be seen to be inserted on a given segment of the stem. Hence alternate arrangement is not irregular as the name " scattered " may imply. The advantage of the alternate arrangement is that the leaves are not thrown into the shade.

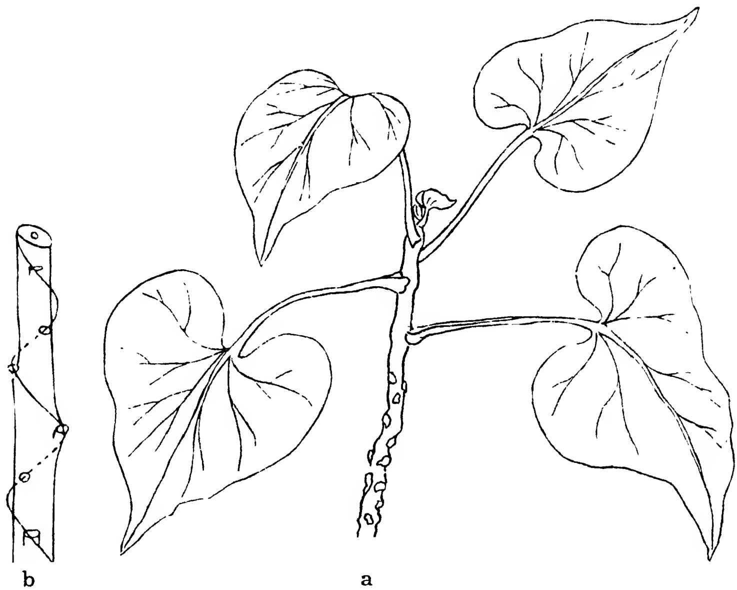
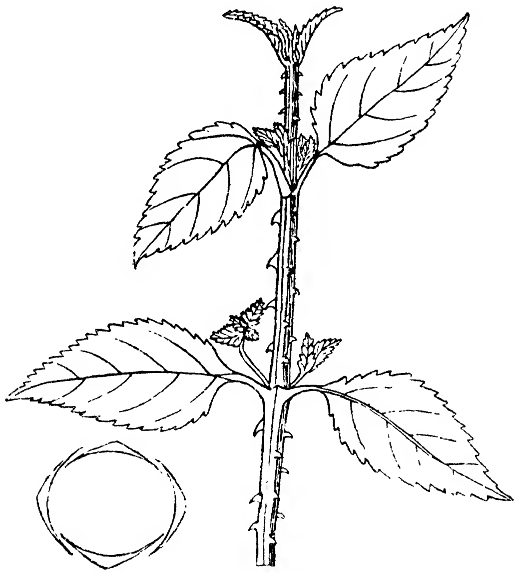


Fig. 62. Alternate arrangement : a. Thespesia ; b. Spiral.

The arrangement is *opposite* when two leaves are inserted opposite to each other at each node as in *Lantana.* The two leaves are separated from each other by 180°. The position of the successive pairs of leaves is also interesting. The second pair of leaves is not placed exactly on the same plane as the pair of leaves at the node below but is placed at right angles to it. A similar principle is followed throughout. Hence the third pair is exactly on the same plane as the first pair and the

fourth pair on the same plane as the second pair. This leads to the arrangement of leaves in four rows and the upper pair does not throw the lower into the shade. There is a pretty long interval between the first and the third pairs and hence there is no danger of shutting out light from the leaves. This arrangement noticed in the opposite type results in the alternation of the members of successive pairs and this alternating feature is described as *decussate.*



b a

Fig. 63. Lantana : a. Opposite decussate ; b. Four rows of leaves.

The arrangement of the leaf is *verticillate* or *whorled* when more than two leaves are produced at each node. The leaves are not crowded together at the same point in the node but are placed equally apart at the node. *Nerium* and *Allamanda* are good instances of this arrangement. Here also the principle of alternation of successive members holds good so that the number of rows of leaves is double the number of leaves in each whorl.

Exposure to sunlight. Sunlight plays an important part with regard to the growth and activities of the leaf. The

Fig. 64. Nerium : a. Verticillate type ; b. Alternation showing six rows of leaves.

green leaf is a very active organ of the plant body and the maximum number of leaves has to be inserted in a limited space. It is essential that the arrangement should be such as not to throw any leaf into the shade for any length of time. The danger of overshadowing is great when the large number of leaves borne by the plant is taken into account. How to minimise this danger ? The different types of arrangement of the leaf prevent to some extent the overlapping of the leaf. There are various other devices which minimise the danger from overlapping and place the leaves in a favourable position. Take the case of plants like the Palms where the large leaves are arranged close together in a tuft. The lower leaves may be shut out from sunlight. But, in these plants, the upper leaves are more or less vertical and the lower leaves are distinctly horizontal. Further,

the petioles of the lower leaves are very long and their blades are placed beyond the reach of the shadow of the upper

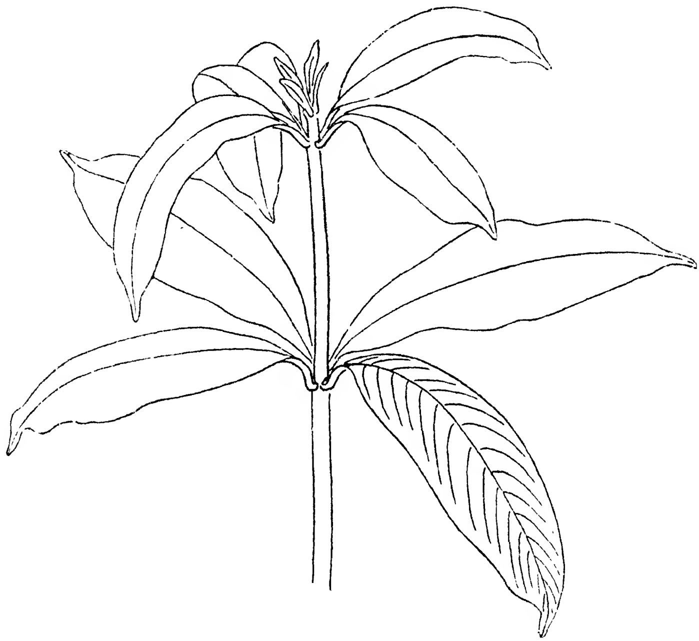


Fig. 65. Allamanda.

leaves. In trees where the danger from the overcrowding of leaves is real, the difficulty does not become serious owing to the compound or lobed nature of the leaves. These leaves allow the rays of light to reach the lower leaves and enable them to do their work. Climbing plants show a peculiar device. In these plants, some of the leaves will be naturally produced on the shaded side of the stem and they will not be in a position to do their work. Very often the petioles of these leaves are *twisted* so that they are turned towards the illuminated side. Some plants show what is known as the *mosaic* type of leaf. In this arrangement the petioles of the lower leaves may be long and blades of varying sizes fit one another so closely as to form a mosaic. The struggle for sunlight is clearly seen from these numerous devices.

Modifications of the leaf. The normal blade is flat, thin and green with an upper surface facing the sky and a lower surface facing the earth. The petiole is a short cylindrical structure with a slight groove on the inner side. In several

Fig. 66. Twisting of the petiole.

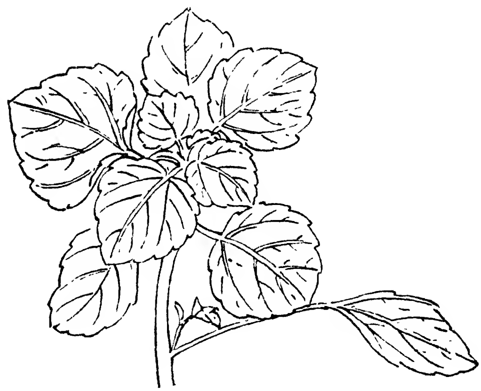


Fig. 67. Acalypha : Mosaic arrangement of the leaves.

cases the base of the leaf may be swollen into a cushion-like structure called *pulvinus.* The parts of the leaf may be modified in different ways. The whole leaf may not be generally modified. More often, only a portion of the leaf is modified.

1. *Scale.* This is a common modification of the leaf met with in subterranean shoots. Owing to arrest in growth, the leaf is modified into a thin dry brown membrane or *scale.* Sometimes the scale may be fleshy as in the bulbs of Onion and Garlic. Even aerial shoots may show scales. *Casuarina* carries at each node a whorl of brown minute scales and this reduction of the leaf to a scale is necessary to minimise the loss of water. Look at the nodes of big bamboos. You will

see at the nodes brown flat dry sheathing scales while the tender shoots carry long green leaves.

2. *Leaf-Tendril.* In certain plants, a part of the leaf is transformed into a tendril which may be called *leaf-tendril* to indicate its leaf-nature. *Gloriosa superba* is a tendril climber in the jungles and the tendril is seen to be the prolongation of the tip of the blade (Fig. 35). This prolonged tip coils like a tendril and acts as a clinging organ. The Pea plant has pinnately compound leaves and the upper pairs of leaflets are modified into fine tendrils. The leaf-nature of the tendril is clear in this plant. In the plant *Smilax* growing in the hills, the two stipules are transformed into tendrils.

Fig. 68. Casuarina : 1. Needle-like stem; 2. Scales.

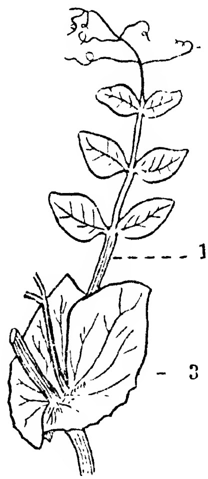


Fig. 69. Pisum : 1. Rachis ; 2. Leaflet-tendril ; 3. Stipule

3. *Leaf-Spine or Thorn.* It is very rarely that the entire leaf is transformed into a thorn. *Asparagus* which is a good scrambler, has the lower portion of the leaf modified into a thorn while the upper portion is transformed into a brown scale. Thus the leaf of *Asparagus* is half scaly and half thorny and its branches also are transformed into flat green cladodes. The stipules of leaves are usually transformed into spines which may sometimes be recurved. The stipular nature can be found out from the presence of thorns in pairs at the node, one on each side of the petiole. *Acacia arabica* which is common everywhere, shows long white thorns which are stipular in nature. Among other plants with stipular thorns may be mentioned *Pithecolobium dulce* and *Zizyphus jujuba.* In the

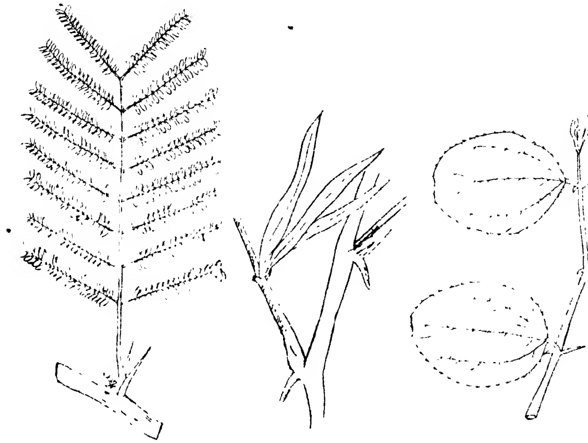


Fig. 70. Leaf-thorn : a. Acacia arabica (stipular); b. Zizyphus jujuba (stipular); c. Asparagus (half thorny and half scaly).

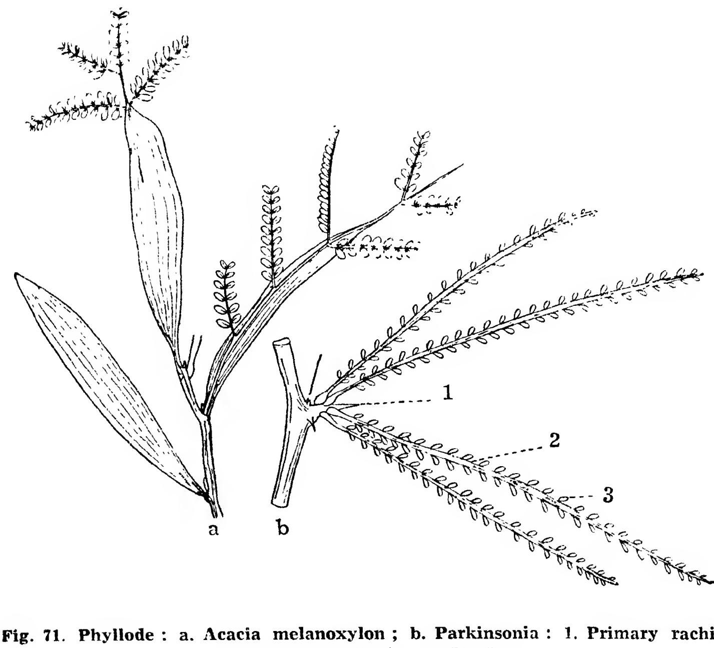
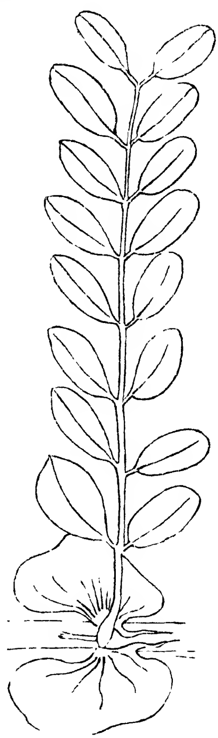


Fig. 71. Phyllode : a. Acacia melanoxylon ; b. Parkinsonia : 1. Primary rachis ; 2. Secondary rachis ; 3. Leaflet.

Prickly-Pear, the fleshy cladodes show the scars of leaves and in their axil a few stout thorns. These stout thorns are regarded as the transformation of the rudimentary leaves of the axillary bud situated in the axil of the original leaf.

There are a few special modifications of the petiole and the stipules to which a reference should be made. The petiole is sometimes transformed into a flat thin green blade-like structure. This modification of the petiole is called *Phyllode* and it is well seen in *Acacia melanoxylon* found in the hills. If the leaves of a juvenile shoot be examined they will be seen to be bi-pinnately compound and the rachises show a tendency to become flat and green. The leaflets fall away and there is seen finally the flat rachis in which veins are distinct. The blade-like phyllodes which alone can be seen on the tree can be easily distinguished from a true blade by their posture. While the true blade is horizontally spread out, the phyllode presents its edges to the sun. *Parkinsonia*, occurring commonly in Madras, shows phyllodes of a slightly different kind. Here the leaf is bi-pinnately compound with the primary rachis reduced to a thorn. There are two or four pinnae closely crowded together on the short rachis. The leaflets on the secondary rachises are articulated and they fall away while the secondary rachises become flattened into long thin green ribbons or phyllodes.



1

Fig. 72. Cassia auriculata : 1. Foliaceous stipule.

Stipules may sometimes appear as fairly large green structures as in *Pisum* and *Cassia auriculata.* They are then described as *foliaceous.* Their transformation into a thorn or tendril has

been already mentioned. They sometimes show special features of growth and give rise to peculiar bodies. There is what is known as the *inter-petiolar stipule* found in *Morinda* and *Ixora.* The leaves are opposite in these plants and there are seen at the node between the petioles of the two leaves

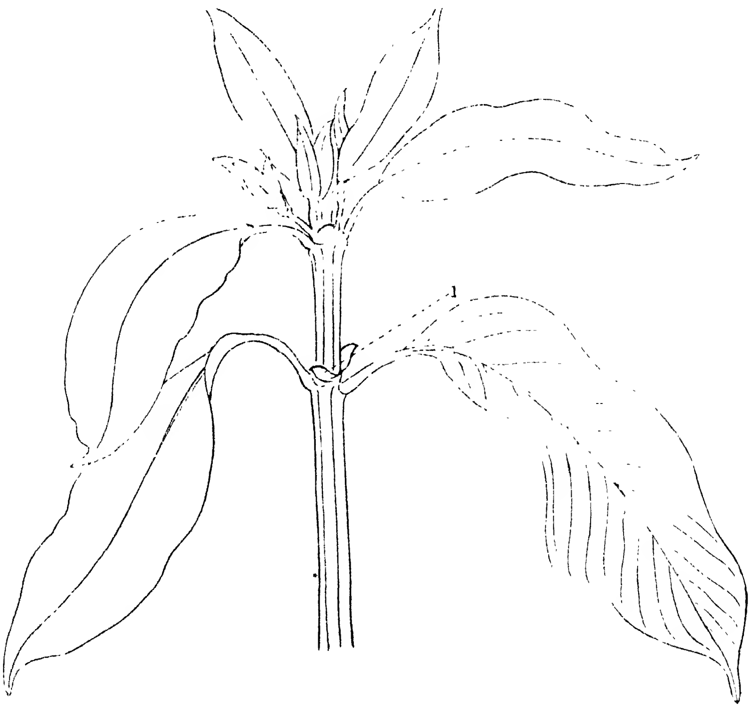


Fig. 73. Morinda : 1. Inter-petiolar stipule.

a pair of green bodies which may sometimes show a small notch. What is the nature of these bodies ? Each of these bodies is formed as the result of the growing together of the two stipules belonging to the two leaves and situated on the same side of the stem. Since such a united body lies between the petioles, it is described as *inter-petiolar.* A more interesting type is the long tubular sheath found at the node of *Polygonum* and extending up the internode. The leaf is alternate in this plant and the two stipules at the node grow

together at an early stage by their free edges. Consequently the two stipules should form a tubular sheath enclosing the internode. Such a sheath is called an *Ochrea* and the stipule is described as *Ochreate.*

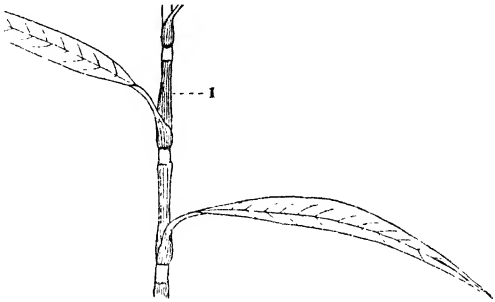


Fig. 74. Polygonum : 1. Ochreate stipule.

Leaf-fall. When the leaf grows old, it shows changes in colour and becomes yellow. Other tints may also be noticed. After the leaf has fallen, there is left at the node a smooth scar, the *leaf-scar*. The fall of the leaf takes place in certain plants in a definite season which is unfavourable for growth. Trees where the leaves are shed all in one season are without any leaf for sometime and these are known as *deciduous* trees. *Evergreen* trees are those where the leaves fall one after another and not all at the same time in one season.

Functions of the leaf. The chief work of the leaf is the preparation of carbohydrates like starch with the help of solar energy. Other organic materials are also prepared here but the leaf is the only structure that can prepare carbohydrates from out of water and carbon-dioxide. This work can be done only when the green leaves are exposed to the sun. The leaves are also useful as structures which facilitate the exchange of gases. The work of the leaf will be described in detail in a later chapter. You have already seen how work of a special kind may also be done by leaves which have become modified. They can act as clinging organs, or as weapons.

SUMMARY

The green leaf has three parts and the blade is the most important part. It arises at the node of the stem and requires to be exposed to the sun.

The forms assumed by the blade are various and the several morphological features regarding the tip, margin, surface and texture should be clearly understood.

The venation of the leaf is of two types and it has a mechanical as well as a physiological significance.

The leaf may be simple or compound and the several forms of compound leaves result from the difference in the degree of branching of the leaf rudiment.

The arrangement of the leaf may be alternate or opposite or whorled and the main point in the arrangement of the leaf is the exposure to sunlight. Leaves show various devices which will prevent the danger from overshadowing.

The leaves are modified in different ways and the modifications are useful to the plant.

The work of the leaf consists in the preparation of carbohydrates and in the facilities afforded to the exchange of gases.

CHAPTER V

BUDS

Characteristics. Buds are small tender bodies found in definite places on the shoot. They represent important active regions of the shoot and the growth of the shoot is due to the continued activity of the bud.

Development. The bud shows a few rudiments of leaves clustered together on a short axis. If the bud be teased out and examined under the lens, the minute axis will be seen and the leaf-rudiments will be arranged on the sides. A longitudinal section of the bud shows under the microscope the leaves over-arching the axis and protecting it. In the axils of the leaf-rudiments, daughter buds are seen. The bud is really a rudimentary shoot and it can, therefore, in course of time, develop into a leafy shoot. When the bud grows, the axis becomes longer and the lower internodes are clearly distinguished. Thus a shoot is formed and the leaves now happen to be separated by internodes in the lower region. The terminal part of the shoot retains the bud nature and hence the shoot can hope to grow indefinitely. That the bud is a shoot becomes clear if you cut a cabbage lengthwise and examine the two halves. The cabbage is a big bud-like shoot.

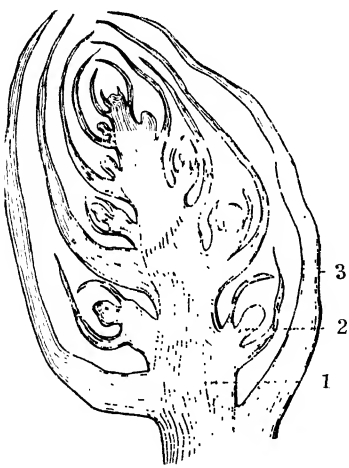


Fig. 75. L. S. of the Bud : 1. Axis ; 2. Axillary bud ; 3. Leaf.

Kinds of buds. Buds are spoken of in different ways. The bud at the apex of each shoot is called the *terminal bud*

on account of its position at the apex. Buds which are present in the axils of leaves are known as axillary buds and they are numerous. Usually, only one bud is found in the axil. If more than one bud be present in the axil, the extra buds may be termed *accessory* buds. It is open to every axillary bud to develop into a shoot and it may be said that the shoot system becomes branched on account of the axillary buds. When the number of axillary buds is considerable, it may not be possible for all the buds to develop into leafy shoots. Many of them may not be favourably placed and consequently they remain inactive, awaiting a suitable opportunity. These buds which are inactive for a long time are by no means dead and their activity may be aroused if the plant be pruned or if a cutting be made and planted separately. Under such circumstances, the buds which have been inactive till now, are stimulated and they manage to grow into shoots. Because of the fact that the activity of the buds has been latent for a long time, these buds are called *dormant buds.* The dormant buds may, from one point of view, be regarded as *reserve buds.* If some branches of a tree be cut as in the process of pruning, the loss is made good by the activity of dormant buds. Ordinarily, buds arise at the apex of the shoot and in the axils of leaves. Sometimes they may arise on other parts of the plant-body, say on a root or a leaf or even on a flowering shoot. Buds which occur in such uncommon places are called *Adventitious buds.* When such buds occur on the root they are known as *radical* buds. When a big root of the Portia tree is injured or cut, shoots make their appearance at the injured part of the root and they arise as

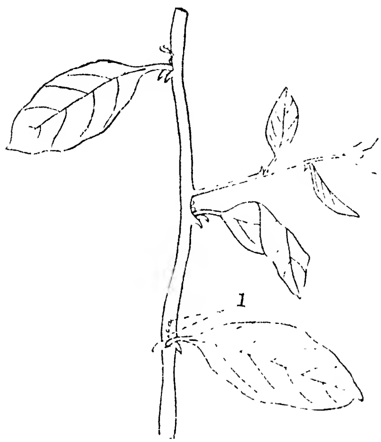


Fig. 76. Capparis : 1. Accessory buds.

radical buds. An interesting form is the *foliar* bud which occurs on the leaf. The fleshy leaf of *Bryophyllum* with which

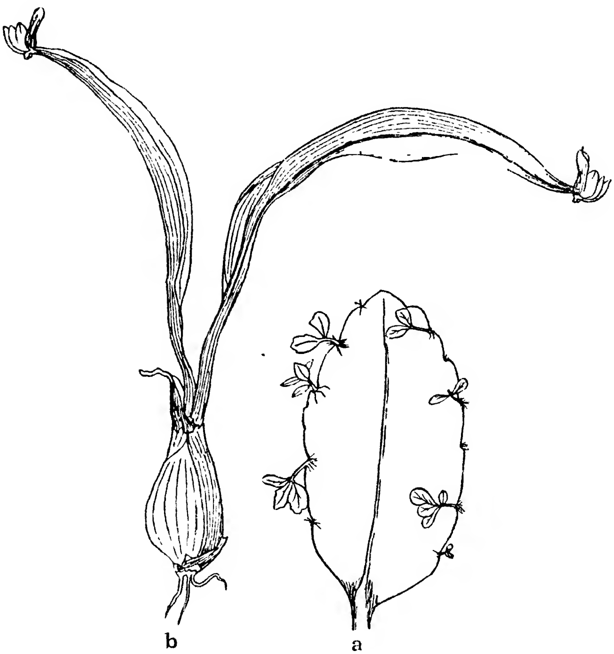


Fig. 77. Adventitious buds : a. Bryophyllum ; b. Scilla.

you are familiar, produces buds at the notches of the margin readily when the leaf is plucked and planted. These buds strike root and develop into new individuals with the help of the materials in the fleshy leaf. By the time the shoots are well developed, the original leaf will have become thin. A small bulbous plant known as *Scilla* is common in Madras bungalows. A few radical leaves come out and each leaf carries at its tip a small outgrowth. This outgrowth is becoming differentiated into a bud even when the leaf remains on the plant. The leaf becomes inclined to the soil and the bud is brought into contact with the soil. It then strikes root and becomes a new plant when the leaf dries up. These are interesting cases where the leaf can be employed for vegetative propagation. This is possible

because of the adventitious buds. Sometimes, in the midst of flowers on the flowering shoot, buds may appear and they may become fleshy. These may be dropped into the soil and may grow into new plants. Such fleshy buds or bulbs close to the flower are called *bulbils* and you find this type in the Onion and the spiny *Agave* common on the railway lines.

Lastly, there is a peculiar type of bud known as the *Resting bud.* As the name itself indicates, it is a bud which passes through a definite period of rest. This necessity for a

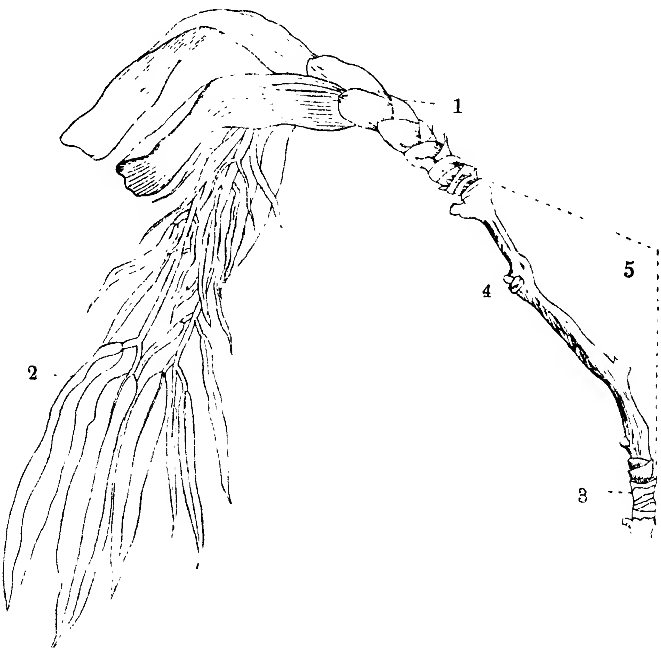


Fig. 78. Brownea : 1. Bud-scales ; 2. Green leaves ; 3. Scars of scales ; 4. Leaf-scar ; 5. Growth in one favourable season.

period of inactivity or rest is felt especially by plants growing in regions subjected to sharp seasonal differences as in the temperate or tropical parts. In the unfavourable season, the plants shed their leaves and the buds are inactive. The resting buds are characterised in several cases by special features which protect them against injury from changes in external

conditions. Examine a resting bud and you will see two kinds of leaves arranged close together on the short axis. The outer leaves are modified into tough, brown, boat-shaped scales with sheathing bases. These are known as *bud-scales* and they are dead structures. They are bad conductors and constitute together a jacket or covering for the tender leaf-rudiments and the axis inside. The inner leaf-rudiments are small and alive. When the unfavourable season is passed, the activity of the bud is awakened and the bud-scales are pushed out and dropped together. These bud-scales leave scars on the axis and these scars are close together. The axis begins to grow in length beyond the region of the scales and the leaf-rudiments develop into green leaves. The growth of the shoot goes on during the favourable season and at the bottom of the shoot can be seen the scars of scales. When the season again becomes unfavourable, the green leaves fall off and their scars are seen at the nodes. The bud passes into the stage of rest or inactivity. With the advent of the favourable season, the bud will again resume its activity. As a result, the bud-scales will be dropped leaving their scars. The axis grows again and the new leaves appear. A long shoot taken from such plants will show, therefore, a short region with the scars of bud-scales alternating regularly with the long region showing the scars of the green leaves placed far apart. The part of the shoot between two successive regions of the scars of the bud-scales represents the growth of one year and it is thus possible to determine the age of the shoot. The resting bud should be distinguished from dormant buds because the inactivity of the former is only for a limited period during the unfavourable season. Plants with resting buds show, therefore, a periodicity or rhythm. In regions where the seasonal differences are not great, the resting bud may not be so well developed but yet the occurrence of scaly leaves during the unfavourable season may be noticed in a number of plants.

Protection. Buds which are tender structures may require protection. There is nothing like a cap covering the bud as in the case of the root and the bud is more or less exposed. But protection may be secured in

several ways. The bud-scales give very good protection especially when they are covered with hairs or with a waxy substance. In *Gardenia gummifera*, there is a sticky fluid secret-

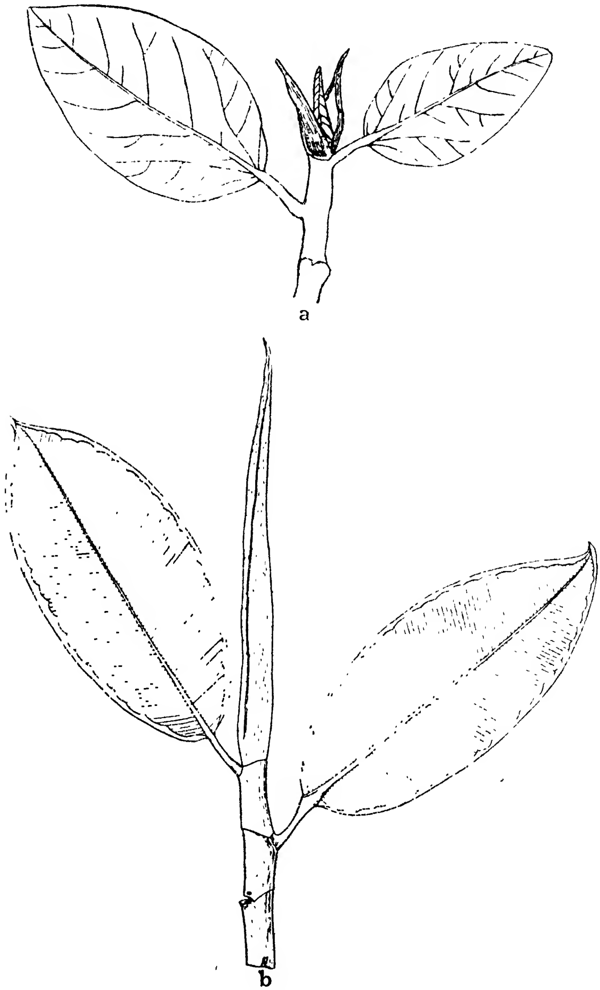


Fig. 79. Bud-protection : a. Ficus bengalensis ; b. Ficus elastica (The India-rubber plant).

ed by the bud which happens to be covered with it. When it develops, the leaves come out and appear as varnished shin-

ing bodies. A good protection may be given by stipules as in the Banyan and the Jack. Here, the two stipules of every leaf are fairly large and hooded. Their bases are sheathing and they extend throughout the node. The two stipules overlap by their edges and thus enclose the bud. When the bud grows, the stipules are pushed out and the scars of the two stipules form a ring at the node. Sometimes, the base of the petiole may be distinctly grooved and the axillary bud may lie in the groove and be well protected.

Organs. The root, the stem, and the leaf are the organs which work in the interest of the individual of which they form part. These are called *vegetative or nutritive organs.* They are of importance to the individual only so long as it is alive. The buds which have been dealt with above develop into leafy shoots and such buds should be regarded as *vegetative buds.* You will be learning hereafter details about the flower. The flower produces seeds with the help of which propagation of plants is normally brought about. Flowers are more important from the point of view of the race and they are known as *reproductive organs.* The vegetative organs are of different kinds and they are distinguished from one another by form, position in relation to one another, and development. The root, the stem, and the leaf form the three different organs of plants. There are several other structures seen in plants, such as thorns, tendrils and so on which look differently. Are these structures new organs which have nothing to do with the normal plant organs ? You have already seen how the plant-organs may be modified. The form of an organ may usually help you to recognise its nature or morphology, but the form cannot always be relied upon. To understand the morphology of an organ, you should observe other characteristics also, such as its position in relation to other organs and development. You know that plants possess certain well-defined organs which may be variously altered to suit external conditions. Two different organs like the stem and the leaf may both take the form of a tendril. More striking is the flat blade-like form assumed by the stem in certain plants and by the petiole in

another. How can one avoid confusion when he is dealing with several structures like the root, the stem, the leaf, the thorn, the tendril and so on ? Organs which can, on the basis of position and development, be shown to be morphologically of the same nature in spite of the difference in form, are described as *Homologous organs.* Thus, the thorn of *Gymnosporia* is homologous to a leafy shoot because the thorn can be clearly proved to be a shoot. Similarly the tendril of the Pea plant and a leaf are homologous, since the tendril of the Pea is easily shown to be the same as the leaflet. The thorn of *Acacia* and the stipules are homologous and the reasons are obvious. When organs of different morphological nature happen to assume a similar form which is useful for a similar purpose, they are described as *Analogous organs.* For instance, the stem of *Cissus* and the leaf of *Pisum* assume the similar form of the tendril. The tendril form is useful for climbing in both cases and hence the tendrils of *Cissus* and *Pisum* are *analogous* organs. The thorns of *Gymnosporia* and *Acacia* are analogous because they are derived from different kinds of organs which assume a similar form to serve the same purpose.

SUMMARY

The bud is a rudimentary shoot. It grows in time into a leafy shoot and the shoot-system becomes much branched owing to the occurrence of numerous buds.

There are different kinds of buds.

Protective structures are commonly developed in connection with buds.

Organs of the plant-body can be divided into vegetative and reproductive organs.

In view of the great scope for modification noticed in the vegetative organs, the morphological nature of the organ may be obscured. Homologous organs are those which are of the same morphological nature irrespective of differences in form and the different forms assumed by the same organ have different purposes to serve. Analogous organs are organs which are morphologically different but which assume a similar form to perform a similar function.

CHAPTER VI

THE FLOWER

Characteristics. The flower is a small but attractive structure. It arises in large numbers on the shoot and appears in the form of a closed bud at the early stage. This bud is known as the *floral bud.* When the bud opens, the parts of the flower are clearly seen.

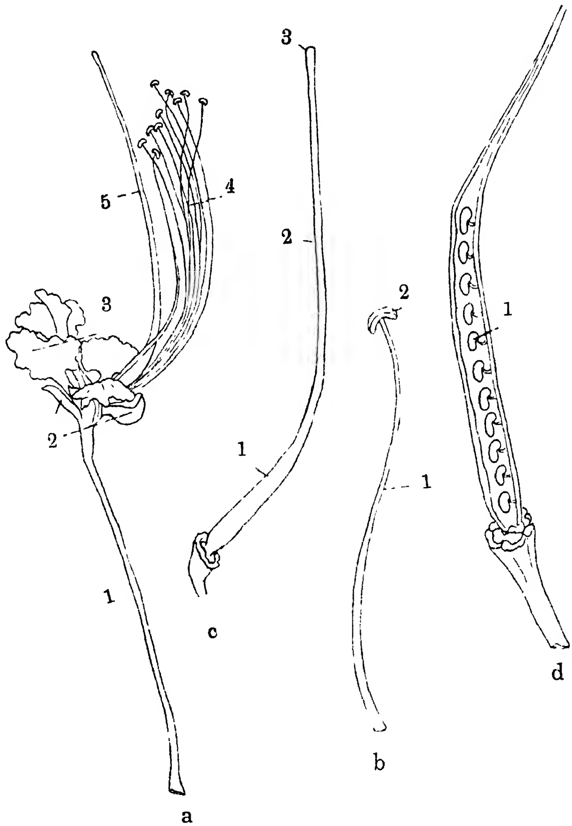


Fig. 80. Caesalpinia : a. An entire flower : 1. Pedicel, 2. Calyx, 3. Corolla, 4. Stamens, 5. Pistil ; b. A stamen : 1. Filament, 2. Anther ; c. Pistil : 1. Ovary, 2. Style, 3. Stigma ; d. Pistil in longitudinal section : 1. Ovule.

Parts of the Flower. Examine the flower of *Caesalpinia.* The flowers are arranged in a cluster on a special shoot, known

as the *Flowering shoot.* The axis of the flowering shoot is called the *Peduncle.* Notice the small leaf-like structures on the axis in whose axils the flowers arise. The stalk of the flower is called the *Pedicel* and the reduced leaf-like structure representing the leaf of the flowering shoot is called the *bract.* The pedicel sometimes carries towards the top just below the body of the flower two small green outgrowths called *bracteoles* which fall off early. The body of the flower shows different parts arranged in a regular manner at the end of the pedicel. Towards the outside, are seen five, leaf-like bodies arranged in a whorl. Each of these leafy bodies is called a *Sepal* and the whorl of sepals is collectively termed *Calyx.* Immediately inside the calyx, are seen five, large, coloured, and attractive bodies. These are called *petals* and the lower part of each petal is narrowed into a stalk, while the upper part is broad and flat. The petals are arranged in a separate whorl of their own and this whorl is collectively called *Corolla.* The petals alternate with the sepals of the calyx and no petal stands immediately in front of a sepal. Inside the corolla, are seen ten slender stalks close together. Each stalk carries at the free end a tender body from which minute particles may be seen to come out. Each of these ten stalked bodies is called a *stamen.* The stalk of the stamen is called the *filament* and the body borne on the filament is known as the *anther.* The anther is an important structure and it produces inside, numerous minute particles or *Pollen grains.* When the anther is ripe, it opens and the pollen grains come out.

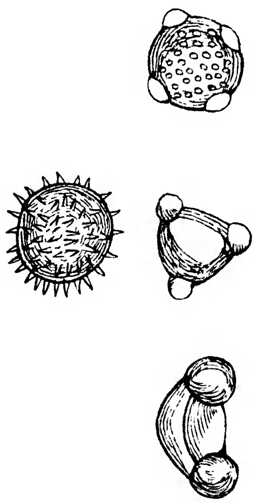


Fig. 81. Pollen-grains.

Each pollen grain represents a **living germ-body.** It has to play a direct and important part in the formation of the seed. The stamens are arranged in two close whorls of five each and

they together constitute the *Androecium.* In the centre of the flower is seen a flat thick structure. This is called the *pistil* which is differentiated into three parts. The lower-most portion is large and hollow and this is called the *Ovary.* A stalk-like prolongation from the ovary is distinctly seen and this is the *Style.* The tip of the style is found to be a sticky point which is called the *Stigma.* The ovary is the most important part of the pistil. Cut the ovary crosswise and you will see that it has a wall enclosing a chamber. If you split the ovary lengthwise, you may easily recognise a few small tender white bodies springing from the wall and projecting into the chamber. These bodies are called *ovules* and inside each ovule **a germ-body quite different from the pollen grain is produced.** This germ-body has also to play an important part along with the pollen grain in the production of the seed. The flower thus consists of four different kinds of structures, the sepals, the petals, the stamens, and the pistil.

Examine the flower of *Tribulus* and compare it with that of *Caesalpinia.* The flower arises singly in the axil of

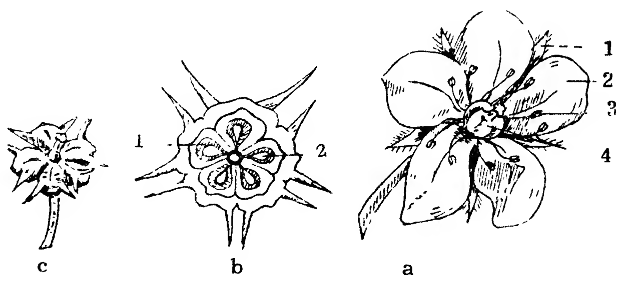


Fig. 82. Tribulus : a. A flower : 1. Sepal, 2. Petal, 3. Stamen, 4. Pistil, b. C. S. of the ovary : 1. Chamber, 2. Ovule ; c. A fruit.

the leaf and it consists of the same parts. The pistil is somewhat flask-shaped and the ovary is a more or less rounded, hollow body with five chambers containing ovules. The style is short and the stigma is a knob-like sticky body. Observe an old flower of Tribulus. You will see the sepals, petals, stamens, and pistil arising from the short dilated top of the pedicel. The parts of the flower arise as appendages on this short, dilated, conical top of the pedicel. When these parts fall

off they leave minute scars on this dilated top. The short conical dilated top of the pedicel is clearly the axis on which the four parts of the flower are inserted close together and **it is the central axis of the flower.** This axis of the flower from which sepals, etc., arise as appendages is called the *Thalamus.* The thalamus is usually small and is shut out from our view by the several appendages grouped close together. The flower seems to be constructed more or less on the same plan as a shoot. What the stem is to a shoot, the thalamus is to the flower. Why is it that the flower appears as a compact structure ? The thalamus is very minute and it may be compared to the stem of a leafy shoot that does not grow in length. The different parts of the flower are not separated by intervals owing to the shortness of the thalamus and they are closely packed together so as to form a compact structure. In a general way, the flower should be regarded as a shoot but it differs from it in appearance and details of structure. This is no wonder when you remember that the flower is not intended to function as an ordinary shoot. It is specialised to function as a reproductive organ. The flower is therefore a **specialised shoot.**

Non-essential and Essential organs. Of the four parts met with in a flower, the outer ones, the calyx and the corolla, play only a secondary part. They do not themselves produce the germ-bodies needed for the production of seeds. They are therefore regarded as *non-essential organs.* They are in the nature of floral coverings, which will, however, be useful to the flower. The calyx gives good protection to the tender parts in the bud stage and the corolla makes the flower very conspicuous and may also secrete, in some cases, honey. The petals attract insects which are able to render valuable help in connection with the work of the flower. The stamens and the pistil are, on the other hand, directly concerned with the production of the germ-bodies and these are therefore regarded as *essential organs.* There are two kinds of germ-bodies produced in a flower, one kind being produced in the anther and the other kind in the ovule. The pollen grains produced in the anther are small living cells and they are carried

to the stigma of a flower by insects or some other agent. Then they resume their activity and germinate. The details of germination will be mentioned later on but it may be stated here that the pollen grain gives rise to a pollen-tube which

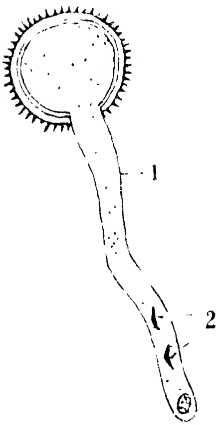


Fig. 83. **Pollen germinating: 1. Pollen-tube ; 2. Sperm-nuclei.**

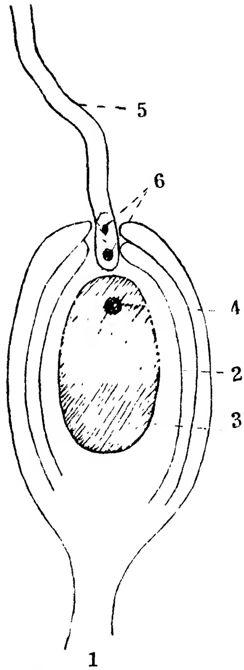


Fig. 84. **Fertilisation : 1. Ovule, 2. Integuments, 3. Embryo-sac, 4. Egg, 5. Pollen-tube, 6. Two Sperm-nuclei.**

goes down the style and reaches the ovule in the ovary. There are produced inside the pollen tube **two small but prominent bodies known as Sperm Nuclei or male sex-cells (sperms in common usage).** The pollen-tube enters the ovule with the two sperms at its tip. By that time a big germ-body is developed inside the ovule. This germ-body does not leave the ovule and the ovule itself continues to remain inside the ovary. The germ-body undergoes changes and there is differentiated in it a **special body known as the egg which is the female sex-cell.** The tip of the pollen

tube which carries the sperms is very close to the egg. The sperms leave the tube and one of them unites with the egg produced inside the ovule. The fusion of the sperm with the egg is known as *fertilisation.* This is an important biological process common among living things and it has a great stimulating effect. The egg which has fused with the sperm is called the *fertilised egg* and the fertilised ovule now develops into the seed. The stamens and the pistil are really the essential organs because they produce the germ-bodies. These germ-bodies (technically called spores) are not themselves sex-cells, but produce on germination the two kinds of sex-cells, **the sperm** and **the egg** respectively.

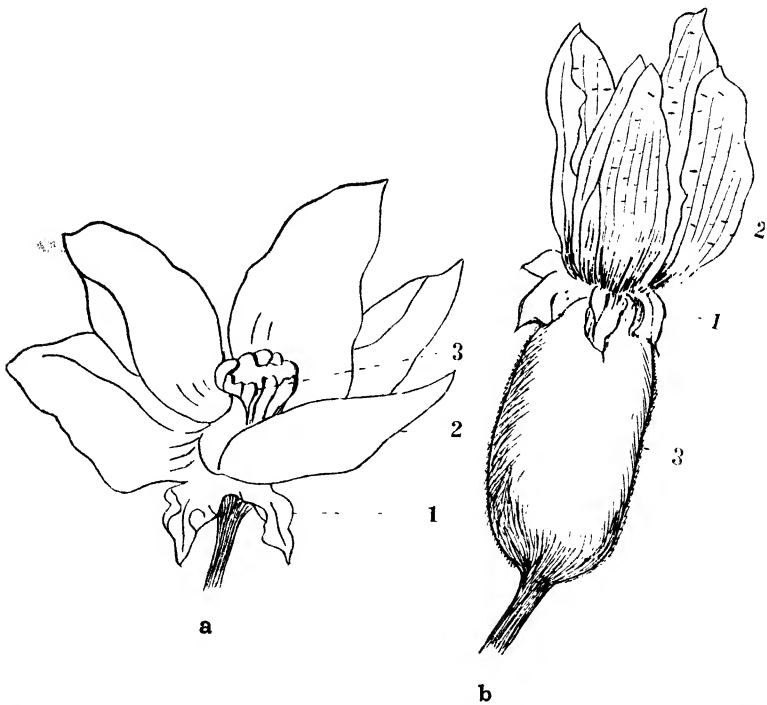


Fig. 85. Diclinous flowers (The Pumpkin): a. Staminate : 1. Calyx, 2. Corolla, 3. Stamens ; b. Pistillate : 1. Calyx, 2. Corolla, 3. Ovary.

Hermaphrodite and uni-sexual flowers. Ordinarily, a flower possesses both stamens and pistil and it is called a *bi-sexual* or *Hermaphrodite* flower. In certain plants like

the Pumpkin and the Castor, a flower shows either stamens or the pistil. Such flowers are termed *uni-sexual* or *diclinous.* The flowers carrying stamens are described as *staminate* and those with the pistil *pistillate.* In plants like the Castor, the Pumpkin, and the Coconut, both kinds of uni-sexual flowers are present on the same plant and this condition is described as *monoecious.* There are plants like the Date and the Palmyra where one plant carries either the staminate or pistillate flowers alone and in such cases the flowers are described as *dioecious.*

Floral structure. There are some general principles governing the construction of the flower and a deviation from these is not very common. The thalamus is short and its internodal portions do not elongate so that the flower is a compact structure. The parts of the flower are arranged in a regular order on the thalamus: and on proceeding from outside inwards, you see the calyx, the corolla, the androecium, and the pistil. The number of members in each part is ordinarily definite and the cyclic or whorled arrangement of the members is a common feature. Members of the successive whorls alternate regularly. The petals do not stand in front of sepals nor do stamens stand in front of the petals ordinarily.

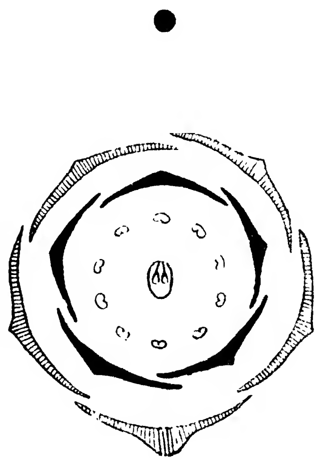


Fig. 86. Floral diagram.

Floral diagram. It is customary to represent the several features of the flower in a diagram known as *Floral diagram.* This is a diagram of how the flower bud will look when cut across or of how the young flower will appear to the observer when viewed from above. It is really a ground plan of the

flower in which you can indicate many details of floral structure, such as the number of members, the whorled arrangement, the alternation of the members, the relation in which the members of each whorl stand towards one another and so on. It is necessary to represent very accurately the parts as you see them. When you observe the flower in the axil of the bract on the peduncle, you have the axis on one side, and the bract on the other side and the flower is between these two. The floral diagram is therefore drawn in relation to the axis. The part of the flower adjoining the axis is called the *posterior* side while the part facing the bract is called the *anterior* side. The two bracteoles may be drawn one on each side of the floral diagram. It is also the practice with some botanists to make use of a floral formula so that the features of the flower may be seen at a glance. For instance, the floral formula for *Caesalpinia* may be as follows :

$$K\,5 + C\,5 + A\,10 + G\,1$$

(K for Calyx, C for Corolla, A for Androecium and G for Pistil.) [It is essential that beginners should construct accurate and neat floral diagrams.]

The Floral Coverings. You will now make a detailed study of the different parts of a flower. The floral coverings are usually differentiated into an outer, green calyx and an inner coloured corolla. The two coverings are also spoken of as *perianth*. The sepals of the calyx are usually green and leaf-like. In some species of *Cassia*, the sepals are coloured and they are then described as *petaloid*. The petals are the attractive structures in the flower and they are of the same number as the sepals. In a few plants like *Anona*, the petals may be greenish, looking like sepals. The terms used to describe the form of the blade may also be used in connection with the description of the form of the sepal or the petal. The sepals of the calyx (or the petals of the corolla) are generally free from one another and appear as distinct members of each whorl. The calyx and the corolla will then be described as *polysepalous* and *polypetalous* respectively. In many flowers, the sepals of the calyx (or the petals of the corolla) may begin to grow together and the calyx or the corolla will then present

the appearance of the sepals or petals having united with one another by their edges. The calyx or the corolla as the case may be, will, no longer, show completely distinct members. If the members of the calyx or the corolla have grown together at a very early stage, it may not be possible to find out easily the number of members. Very often they appear to grow together up to the middle or so; and portions are left free at the top as minute teeth or as somewhat distinct lobes. The number of teeth or lobes will give an indication of the number of members present in a whorl. When the sepals or petals grow together, they are described as *gamosepalous* or *gamopetalous* as the case may be. In a united calyx or corolla, the lower united part is known as the *calyx tube* or the *corolla tube* as the case may be and the entrance into the tube is spoken of as the *mouth* or *throat*. It should not be supposed that the growth of the calyx has anything to do with that of the corolla or *vice versa*. The forms assumed by the united calyx or corolla may be various and the following terms are employed to describe these forms. Some of the common forms are the following:

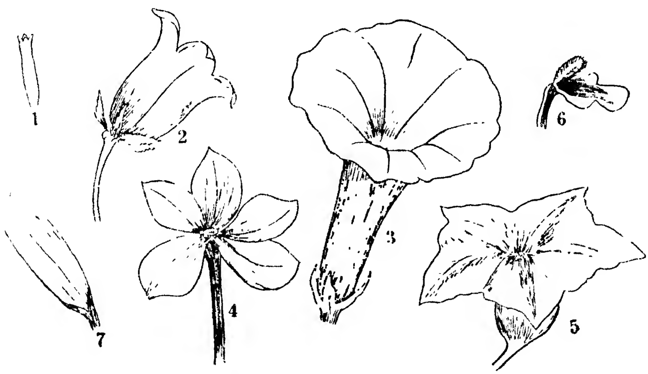


Fig. 87. Forms of the corolla: 1. Tubular, 2. Campanulate, 3. Funnel shaped, 4. Salver shaped, 5. Rotate, 6. Bi-labiate, 7. Ligulate.

(1) *Tubular*, if the united portion be in the form of a small or narrow tube;

(2) *Campanulate*, if it be shaped like a bell;

(3) *Funnel-shaped*, if it be like a funnel;

(4) *Salver-shaped,* if the tube be long and narrow and if the lobes be spread out at right angles to the tube at the throat ;

(5) *Rotate,* if the lobes be spreading widely from a short tube ;

(6) *Bi-labiate or Bi-lipped,* if the tube should divide higher up into two unequal parts and if these should overhang each other like the lips. The upper part is called the *upper lip* and the lower part is called the *lower lip* ;

(7) *Ligulate,* if the body be flat and strap-shaped.

Symmetry. Of the various forms mentioned above, all except the labiate and ligulate forms show one common feature. The members of the calyx or of the corolla are similar in form and size and the symmetry of the flower is not therefore disturbed. The same feature may be noticed in plants like *Tribulus* where the sepals and petals are polysepalous and polypetalous respectively. Such flowers where the sepals of the calyx as well as the petals of the corolla are similar in form and size, are called *Regular* flowers. When the members of the calyx or the corolla happen to differ among themselves in form or size or in both, the symmetry will be different and such flowers are described as *Irregular* flowers as, for instance, the bi-labiate and ligulate types. What about the flower of *Dolichos* or *Crotalaria* ?

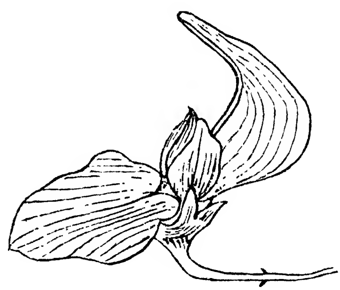


Fig. 88. Crotalaria.

Aestivation. The manner in which the sepals of the calyx or the petals of the corolla stand towards one another in the bud is known as *Aestivation.* The following terms may be used in respect of both calyx and corolla and these parts should be observed separately in the bud. It is possible to indicate the aestivation also in the floral diagram.

(1) *Valvate,* if the members should stand close together with the adjoining sides just touching each other, e.g., calyx of *Hibiscus.* Members open simultaneously in this type.

1 2 3 4

Fig. 89. Aestivation : 1. Valvate, 2. Induplicate, 3. Convolute, 4. Imbricate.

(2) *Induplicate,* if the members should stand close together and if the adjoining edges should slightly fold inwards and touch each other, e.g. calyx of *Poinciana.*

(3) *Convolute or Twisted,* if the members should overlap regularly in the same direction by the adjoining edges so that one edge of every member is overlapping and the other edge is overlapped. The effect of this kind of overlapping is a twisting of the calyx or the corolla and the opening of the flower is a process of untwisting, e.g. corolla of *Hibiscus* where nearly one-half of each petal is overlapped.

(4) *Imbricate.* Here also is noticed the tendency for overlapping but the overlapping is not proceeding regularly in the same direction. Very often one member at least is completely overlapped while the two edges of another member are free. The members can open only one after another in this type, e.g., corolla of *Crotalaria* or *Caesalpinia.*

Androecium. The Androecium consists of a cluster of stamens. The number of stamens may be the same as that of sepals or petals or double the number. In certain cases, as in the Lotus, the number may be very many. A reduction in the number of stamens is also noticed in certain flowers. When the stamens are free from one another in the flower, they are described as *polyandrous,* e.g., the Lotus. They may also be united in different ways. All the stamens may unite to form one bundle and this condition is known as the *Monadelphous* type as in *Hibiscus.* The united part may be a small cup or

tube or an open sheath and the filaments will project from the united portion. Sometimes the stamens may unite to form two bundles and this condition is described as *diadelphous*. The

Fig. 90. Condition of Stamens : 1. Monadelphous (Hibiscus); 2. Diadelphous (Dolichos); a. Bundle of 9, b. Single free stamen ; 3. Polyadelphous (The Castor plant).

number of stamens in each of the two bundles need not be the same. For instance, the flower of *Dolichos* has diadelphous stamens with nine stamens in one bundle and a single stamen in the other bundle. When more than two bundles are formed, the condition is called *polyadelphous*. In *Bombax* or Silk-cotton tree there are five bundles and in the male flower of the Castor plant there are several branching bundles.

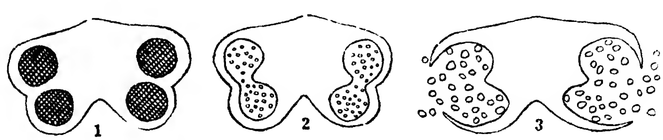


Fig. 91. Anther in cross-section : 1. Young stage ; 2. Later stage ; 3. Ripe stage.

Anther. The anther is the more important part of the stamen. If the filament be absent, the anther is described as *sessile*. The form of the anther may be oblong, or boat-shaped,

or kidney-shaped, or sagittate. A young anther shows a deep groove running along the middle of the body and dividing it into two lobes. The part of the anther showing the long groove is called the *face* while the opposite side is the *back*. The two lobes of the anther are close together and run parallel to each other. When the young anther is cut crosswise and examined under the microscope it is roughly oblong in appearance and shows four active regions, two for each lobe (one at each corner). As the anther grows, the two active regions belonging to each lobe and producing pollen grains become one by the disorganisation of the partition and the numerous pollen grains are now lying loose inside each anther lobe.

Attachment of the anther. The anther is borne at the top of the filament. The attachment of the anther to the filament may be firm or delicate. There are three modes of attachment seen in flowers.

(1) *Adnate or Dorsifixed.* Here the top of the filament shows a tendency to grow along with the anther and extend as a ridge-like tissue along the back of the anther. The anther appears as if its entire back is in contact with a tissue and hence the attachment is termed *adnate* or *dorsifixed*. The anther is kept firmly attached and the extended tissue of the top-point of the filament is called the *connective*. This connective is well seen in the flowers of the Plantain and Water-Lily.

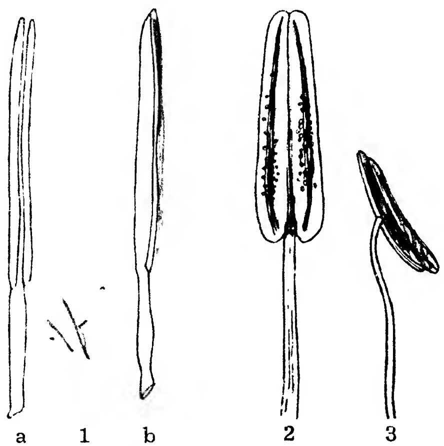


Fig. 92. Attachment of the Anther : 1. Dorsifixed : a. Front view, b. Side-view ; 2. Basi-fixed ; 3. Versatile.

(2) *Basifixed.* In this mode, the anther is attached by its base to the top of the filament which does not show any tendency to grow along with anther. Hence the connective is

not well developed and the attachment is not quite so firm as in the previous form, e.g., *Solanum.*

(3) *Versatile.* Here the filament is attached to a point in the middle of the back of the anther. There is no marked development of the connective and the anther is balanced as it were on the top of the filament. The anther is easily moved to and fro by currents of wind, e.g., *Crinum.*

Dehiscence of the Anther. When the anther is ripe, its wall gives way and the pollen-grains produced inside the lobe manage to come out. The opening of the anther is technically termed *Dehiscence* and there are different modes of dehiscence.

(1) *Longitudinal slits.* Each lobe of the anther will show, even when young, a gentle line looking like a faint scratch extending throughout its length. This is the region where the wall of the anther is to give way. Each lobe opens separately and in the place of the faint line, there is clearly seen in the ripe stage, a fine slit. The wall of the anther splits along this line and the slit is formed. Pollen grains come out through the longitudinal slits and there are two slits for the anther, one for each lobe. This mode of dehiscence by longitudinal slits is very common as in *Caesalpinia* and *Ipomaea.*

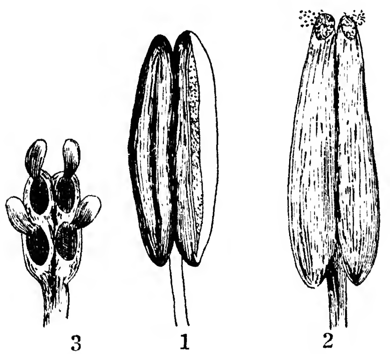


Fig. 93. Dehiscence of the Anther : 1. Longitudinal slits ; 2. Apical pores ; 3. Valves (Two for each lobe).

(2) *Porous Dehiscence.* In plants like the Brinjal and the Tomato, each lobe shows a fine pore at the top and the pollen grains are sent out through the pore when the stamen is shaken by wind. The porous dehiscence is not very common. *Cassia* also shows this mode of opening.

(3) *Valvular dehiscence.* This is an uncommon mode seen in a few plants like *Cinnamomum.* Here a portion of the wall of each anther lobe is partially separated into a flap-like body and this remains attached to the anther at the top. This flap is hygroscopic and it is influenced by the humidity of the atmosphere. In wet weather, the flap is closely pressed to the anther and it therefore closes the aperture. The pollen grains are thus prevented from leaving the anther when the weather is unfavourable and wet. In dry conditions, the flap is lifted up and the pollen grains find it easy to leave the anther. The flap is working in the manner of a valve and hence the dehiscence is described as *valvular.*

Staminode. Ordinarily, stamens develop properly and the anther is able to produce pollen grains. In some flowers, some of the stamens may fail to develop. The filament may be short and the anther is much reduced. It is clear that a stamen of that type cannot function and such stamens as fail to develop properly and produce pollen are called *Staminodes.* This is very clear in *Tecoma* where one of the five stamens is reduced to a staminode.

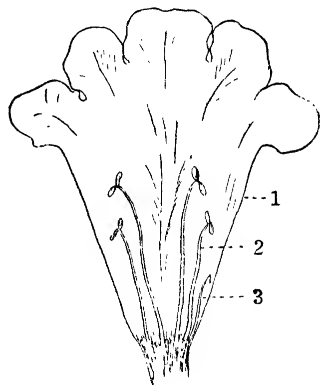


Fig. 94. Tecoma : 1. Gamopetalous corolla spread out with epipetalous stamens ; 2. Well-developed stamen ; 3. Staminode.

Epipetalous stamens. Stamens usually arise on the thalamus. In gamopetalous flowers, the stamens are seen to adhere to the corolla tube and fall away along with the corolla tube. The stamens in the case of these flowers have grown along with the corolla. This condition of stamens which is seen in all gamopetalous flowers is described as *epipetalous.*

The Pistil. The pistil is the innermost part of the flower and is borne at the terminal point of the thalamus. You know it is differentiated into three portions, the most important part

being the ovary. The ovary has a wall enclosing one or more chambers and the ovules arise at definite points on the wall of the ovary. The ovary gives protection to the tender ovules and they develop in the chamber of the ovary and continue to remain in it until fertilisation takes place. The stigma which is a sticky knob or a hairy brush is intended to receive the pollen grains carried by the insect or wind and it is therefore a receptive structure. Pollen grains may easily adhere to the sticky stigma or be easily held between the hairs on the brush-like stigma. It is necessary that the stigma should be placed in a favourable position and this is secured by the style which serves to make the stigma protrude. There are a few flowers where the style is absent and the stigma is then described as *sessile.* The pistil looks entirely different from the other parts of the flower. While the sepals and petals resemble leaves in certain respects, the stamens and the pistil seem to be peculiar structures. Because the stamens and the pistil produce the germ-bodies or

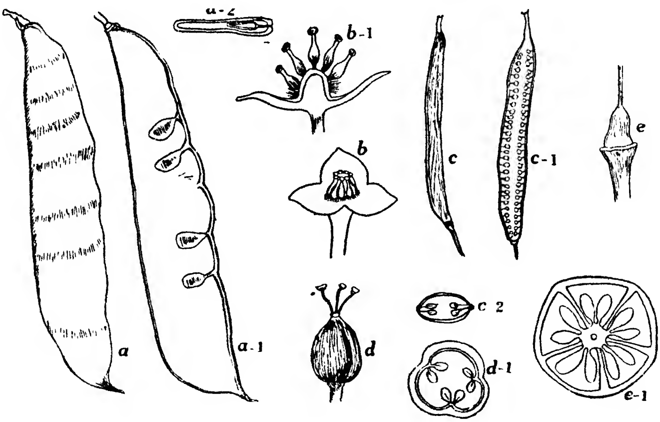


Fig. 95. Types of Pistil : a. Pistil of Caesalpinia : a-1. L. S. of the same, a-2. C. S. ; b. Pistil cluster in Polyalthia : b-1. Same enlarged ; c. Pistil of Cleome : c-1. L. S. of the same, c-2. C. S. ; d. Pistil of Passiflora : d-1. C. S. of the same ; e. Pistil of Hibiscus : e-1. C. S. of the same.

spores, they are regarded technically as *sporophylls* (spore-producing leaves). If you observe the pistils of different flowers, you may see wide differences in form, size, and structure.

You may be curious to know how the pistil has become differentiated. You will do well to examine a few flowers to have an idea of the variations in the pistil. In *Caesalpinia* the pistil is rather flat with a single chamber in the ovary. If you cut it lengthwise and examine it, you find the ovules attached to one side only. If you observe the pistil of *Polyalthia*, it is seen to be very peculiar. Instead of a single pistil, you notice a cluster of numerous small independent pistils, each with an ovary and a stigma. Take the case of the pistil of *Cleome*. The ovary is long and narrow and cylindrical and the style is short. The ovary shows one chamber but the ovules are arranged in two lines as against the single line of ovules in *Caesalpinia*. What about the pistil of *Hibiscus*? The ovary is round and five-chambered and the single style is branched at the top into five bodies, each of which carries a fine cushion-like stigma. As for the arrangement of the ovules in this plant, they are all clustered together at the centre of the five-chambered ovary, one cluster of ovules being found in each chamber. How can we explain these differences.

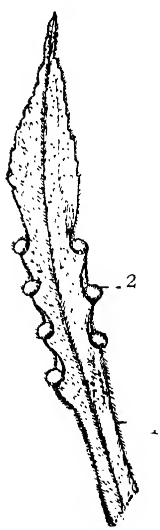


Fig. 96. Cycas : A Single sporophyll : 1. Leafy part ; 2. Ovule.

Origin of the Pistil. It is presumed that a pistil is built up of a varying number of flat leaf-like structures called *carpels*. The number of carpels which go to make up the pistil varies from one to many. The carpellary structure may be supposed to have given rise to a pistil by certain peculiar features of growth ; and the differences in the pistil are to be attributed to the differences in the number of carpels and the manner of growth. That the pistil may have been formed out of a flat leaf-like structure can be inferred from the existence of such a structure in a small group of flowering plants represented by *Cycas*. Here, you do not see anything like a pistil but a number of big ovules are borne on the free edges of a flat brown leaf-like structure. These ovules

are therefore exposed and naked. You cannot see this flat carpel itself in *Caesalpinia,* etc., but a flat carpel should have given rise to the pistil. Imagine a single leaf-like carpel with ovules borne on the two free edges to fold itself lengthwise on its mid-rib and to get the ovule-bearing free edges to grow together. A single-chambered flat ovary with two margins will be formed. One margin corresponds to the mid-rib and is taken to be the *dorsal suture* and the other is newly formed by the coming together of the ovule-bearing free edges. This new margin alone can bear the ovules and is known as the *ventral suture.* If the free end of the carpel be imagined to be drawn out, a style will be differentiated and a stigma will be then evolved when the tip of the style becomes a knob. A single carpel can therefore be expected to produce a simple pistil of the type found in *Caesalpinia.*

Types of Pistil. In *Caesalpinia,* therefore, the pistil may be regarded as built up of a single carpel and this is evident from the single-chambered ovary and from the single line of ovules present in the ventral suture alone. A pistil built up of one carpel is described as *Monocarpous.* How can you explain the cluster of pistils in *Polyalthia?* Imagine a large number of carpels to remain close together and to develop independently. Each and every one of the numerous carpels can give rise to a simple pistil similar to that of *Caesalpinia.* Owing to the occurrence of a large number of carpels in the flower, a number of independent pistils must be produced and thus you get the cluster. This type of pistil is certainly different from that of *Caesalpinia* and it is described as *Apocarpous.* It is clear from these two instances that the number of carpels need not be the same as the number of sepals or petals. Very often the carpels are fewer in number and there may be only one carpel as in *Caesalpinia.* The terms, calyx, corolla, and androecium are employed to stand for the cluster of members in a whorl; and it may be convenient to have a term, *Gynœcium,* for the cluster of carpels (Gynœcium is a technical term for the pistil in general). A *gynœcium* with one carpel will be a simple *monocarpous pistil.* A gynœcium with a cluster of independent carpels will show a complex

cluster of independent pistils and is regarded as *Apocarpous*. More often the gynœcium consists of a definite number of carpels, say two, or three or more, and these are arranged in a whorl. These carpels grow together and hence the gynœcium will neither be of the monocarpous type nor of the apocarpous type. When the gynœcium is formed by the union or the growing together of a number of carpels, a single compound pistil is formed and such a gynœcium or pistil is described as *Syncarpous*. This is a very common type found, for instance, in *Cleome*, *Passiflora* and *Hibiscus*. There are two forms of syncarpous pistil and the difference between the two is due to the difference in the mode of growth of the carpels. One form of the syncarpous pistil is seen in *Cleome* and *Passiflora*. In both cases, you see a single-chambered ovary but in the former there are two lines of ovules as against the three lines of ovules arising from the wall of the ovary in the latter. Let us take the case of *Cleome*. Imagine two carpels with ovules on the free edges standing face to face. If the adjoining free edges of the two carpels should grow together, the two carpels will together form a single-chambered ovary and a line of ovules should appear at each line of junction of the two adjoining edges. Since *Cleome* possesses two lines of ovules in the ovary its pistil should be supposed to be built up of two carpels. The number of lines of ovules in the ovary thus corresponds to the number of carpels. The pistil of *Passiflora* is of the same type as that of *Cleome* but it is built up of three carpels since you see three lines of ovules. A syncarpous pistil formed by the growing together of the free edges of the few carpels arranged in a whorl will thus have a single compound pistil with a *unilocular* or *one-chambered ovary*. In what way is the pistil of *Hibiscus* different ? Cut a cross-section of the ovary and you will find the wall of the ovary enclosing five chambers. The five chambers are separated from one another by partitions extending throughout the ovary. Notice the arrangement of the ovules. There is one line of ovules in each chamber and the five lines of ovules are clustered together at the centre of the ovary round about a central axis. How is it that the ovary is five chambered and that the ovules are collected at the centre ? The five lines

of ovules suggest the presence of five carpels. The five carpels with ovules on the free edges grow in a slightly different manner. The free edges of every carpel carrying ovules begin to fold inwards in the first place. They continue to fold inwards further and further until each carpel forms a chamber as usual when its free edges come together as ventral suture. During this phase, the infolding edge of one carpel will be close to the infolding free edge of an adjoining carpel. As chambers are being formed, the pairs of adjoining infolding edges belonging to the adjacent carpels also grow together. Consequently the five chambers of the five carpels form a single *multi-locular* or *many-chambered ovary* with five partitions; and each partition separating one chamber from another is morphologically standing for the two adjoining infolding carpellary edges. If A, B, C, etc., should stand for carpels and if p should represent each partition, then

$$p = \tfrac{1}{2}A + \tfrac{1}{2}B \text{ or } \tfrac{1}{2}B + \tfrac{1}{2}C \text{ or so on.}$$

Further, the ovules of each carpel should be present at the ventral suture when a pistil is formed; and owing to the infolding of carpellary edges, the ventral sutures of the five carpels which are directed inwards meet in the centre. Hence there is one line of ovules in each chamber at its ventral suture and the five lines of ovules should therefore be crowded together at the centre. Thus, the different types of pistil can be easily derived from the hypothetical carpel assumed by us. The union of carpels may be complete or partial. If it be complete right through, there will be a single compound pistil with a single ovary, a single style and a single stigma. Sometimes the union may not extend to the top as in *Hibiscus* in which case the styles and stigmas will appear to be branched.

Placentation. The ovule is attached to the wall of the ovary and the region of the wall to which the ovules are attached, shows a thick ridge-like outgrowth, called *placenta.* The stalk which attaches the ovule to the placenta is called the *Funicle* through which food-materials needed for the growth of the ovule are carried. The mode of arrangement of the

ovules in the ovary is called *placentation* and it depends upon the number of carpels and the nature of union among them.

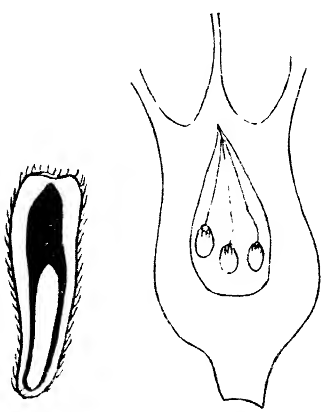
(a) *Marginal.* This is a type of placentation where the ovules are arranged along only one margin, the ventral suture. It is clear that this type can occur only in the monocarpous type of pistil as in *Caesalpinia* and *Dolichos* (Fig. 95, a-1).

(b) *Parietal.* This is a form met with in syncarpous pistils with a unilocular ovary (Fig. 95, c-2 and d-1). Here the several placentae are arranged at equal intervals on the inner surface of the wall of the unilocular ovary, one placenta being found at each line of junction of the two adjoining edges, e.g., *Cleome* and *Passiflora.* Each placenta thus belongs partly to one carpel and partly to the adjoining carpel. If p should stand for placenta and A, B, C for carpels in *Passiflora*,

$$p = \tfrac{1}{2}A + \tfrac{1}{2}B,\ \tfrac{1}{2}B + \tfrac{1}{2}C,\ \tfrac{1}{2}C + \tfrac{1}{2}A.$$

(c) *Axile.* This is a type of placentation where the several placentae are closely aggregated together at the centre of the ovary owing to the meeting together of the ventral sutures of all the carpels in the centre. This type is seen in syncarpous pistils with a multi-locular ovary as in *Hibiscus* (Fig. 95, e-1). Here each placenta belongs exclusively to the chamber in which it occurs.

$$p = A \text{ or } B \text{ or } C, \text{ etc.}$$



1 2

Fig. 97. Placentation : 1. Basal ; 2. Pendulous.

There are a few uncommon types of placentation which cannot be included in the above-mentioned forms. In the Sunflower family, the ovule is single and is attached by its base to the base of the ovary. This is termed *Basal Placentation.* In the pistil of the Rangoon creeper, the ovules are suspended from the top of the ovary and they are described as *pendulous.*

The Thalamus. The Thalamus is the axis of the flower and it carries, as appendages, the parts of the flower in quick succession and in a regular order. It is generally short and cannot be seen unless the floral parts are removed. There are some flowers where the thalamus is fairly long. A portion of the thalamus between the successive whorls is seen to have grown in length. Consequently, the different whorls are not close together and the flower is not very compact. In *Gynondropsis*, the sepals and petals are arranged on the top of the pedicel close together as usual. The stamens are not found close to the corolla but are separated by a fairly long internode. Evidently the part of the thalamus between the corolla and the stamens has grown in length and this elongating region corresponds to an internode of a leafy shoot. Again, the pistil is not placed close to the stamens but is lifted up by the elongating thalamus. It is clear that the thalamus may become long and prominent. Its axis-nature is thus made plain. But the thalamus is ordinarily very short and it forms a small conical dilated part of the top of the pedicel. In some cases the thalamus may grow differently and lose its conical form. It may become flat or cup-shaped. When the form of the thalamus becomes different, the appearance of the flower may be somewhat altered. The common form of the thalamus is that of a cone and on this conical structure the floral whorls are produced in quick succession and arranged close together. The calyx, the corolla, and the stamens are found arranged one a little above the other and the pistil overtops the rest of the flower. Since the parts other than the pistil stand lower down in relation to the pistil, the flower is usually described as *Hypogynous* as in *Cleome*. The ovary which is distinct by itself is described as *superior* and the calyx which is the lower-most whorl is termed *inferior*. The corolla and the stamens are described as *hypogynous*. In flowers where

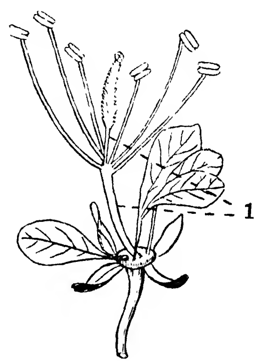


Fig. 98. Gynondropsis : 1. Thalamus elongating.

the thalamus is long or conical, the pistil will be overtopping the rest and independent and hypogynous condition will be noticed. Sometimes, the thalamus may show more vigorous growth at the sides in the early stages and it may become a flat or even cup-shaped structure. The cup is known as the *thalamus cup* and the terminal growing point will be at the bottom

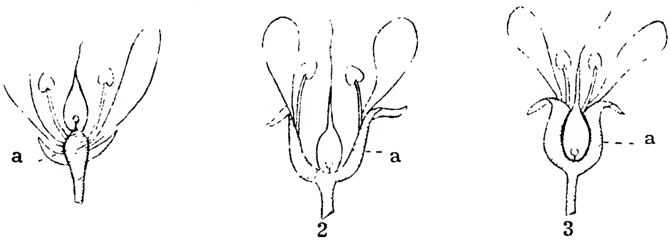


Fig. 99. Types of flowers : 1. Hypogynous ; 2. Perigynous ; 3. Epigynous ; a. Thalamus in all cases.

of the cup. The sepals, petals, and stamens arise at the edge of the thalamus cup, one inside the other and the pistil is found in the middle of the cup situated more or less on a level with the other parts and surrounded by them. This flower will be different in appearance from the previous type and this is known as *perigynous flower*. The ovary is still described as superior since the pistil is free from the other parts ; and the calyx is described as inferior. The corolla and the stamens are described as perigynous. This type of flower is noticed in *Caesalpinia* and the Tamarind. The Rose represents an extreme type of perigynous condition. The thalamus cup is very deep and it is somewhat constricted at the top. The sepals, the petals and the stamens arise at the edge of the thalamus cup and the pistil is placed in the cup. This deeply perigynous type leads to the third type of flower known as *Epigynous* flower. Imagine a deeply perigynous flower with a multilocular or simple ovary seated at the bottom of the cup. Suppose the ovary becomes bigger and bigger and its wall becomes thicker and thicker. Very soon the thalamus cup which accommodates the pistil will be filled up by the enlarging ovary and the wall of the ovary will become organically united with the wall of the thalamus cup at an early stage as in Guava and Pumpkin. It will then be difficult

to recognise the thalamus cup and the pistil as distinct bodies. It may appear strange to you that the ovary should be so clearly visible in Guava and that it should also carry at the top the calyx, the corolla and the stamens. What is taken for the ovary in such cases is not the ovary alone but really the ovary surrounded by the thalamus cup. When the ovary becomes one with the thalamus, the sepals and other structures which are borne at the edge of the thalamus cup should appear to be borne directly on the ovary itself. Since the sepals, petals and stamens are apparently borne on the ovary itself, the flower is described as *Epigynous* and the ovary is termed *inferior*. The calyx will now be described as *superior* and the corolla and stamens will be termed epigynous.

Function of the Flower. The flower is the reproductive organ of the plant. It produces the germ-bodies or spores within which the sex-cells, the sperm and the egg, are differentiated in course of time. The formation of the seed which is the ultimate work of the flower is connected with the process of fertilisation. You have already seen how the sperm is carried to the egg in the ovule by the pollen-tube and how it finally fuses with the egg. In order that fertilisation may take place, it is essential that the pollen grain should be carried to the stigma. The transport of pollen and the deposition of the same on the stigma should precede fertilisation and the floral coverings take a prominent part in helping this transfer of pollen by external agents like the insect. This transport or transfer of pollen from the anther to the stigma is called *pollination.* The details of pollination will be described later on under the section of physiology. An important aid to pollination is the honey or nectar which is secreted in most flowers. The honey is secreted by special glands which may develop on the petals or sometimes on sepals; and very often the thalamus itself carries near the pistil special glands which secrete *nectar.* In the flowers of *Ipomaea,* the nectar-secreting glands join together to form a fine ring-shaped body or disc. Any structure that is specialised to secrete nectar is called a *nectary.* The morphology of the individual flower has been dealt with so far

and it now remains for us to study the arrangement of flowers on the shoot.

SUMMARY

The flower is a specialised shoot consisting of an axis which carries different kinds of structures as appendages.

The floral coverings are the non-essential organs and they assume various forms.

The stamens produce in special regions of the anther a large quantity of pollen-grains which are a kind of germ body. These leave the anther and on reaching the stigma become active and produce sperms.

The pistil is a complex structure formed from carpels and produces inside the ovary numerous tiny ovules in which a different kind of germ body is produced. When this germ body begins to be active, an egg is produced in it.

The thalamus is usually a short conical axis but it becomes flat or cup-shaped in certain cases. The thalamus may also grow along with the wall of the ovary situated inside. The form of the flower is likely to be altered by the variations in the growth of the thalamus.

The floral diagram is the representation of the ground plan of the flower and most of the features of the different parts of the flower can be clearly indicated in the diagram.

CHAPTER VII

INFLORESCENCE

The Flowering Shoot. The arrangement of flowers on the plant is termed *inflorescence* and, in common language, the word " inflorescence " is also used to stand for a cluster of flowers. Generally, flowers are borne on separate branch shoots springing from the shoot system. Sometimes the top portion of a leafy shoot may itself be set apart exclusively for the production of flowers. Shoots which carry flowers alone as in *Caesalpinia* are called *flowering shoots.* These resemble the leafy shoot in regard to the plan of construction but do not carry the large green leaves characteristic of the leafy shoot. The flowering shoot has an axis which is known as the *Peduncle* and this is differentiated into nodes and internodes. At the nodes are seen rudiments of leaves but these never develop into large green structures. They often appear as tiny, reduced, greenish flat bodies and are therefore called by a special name, *bract.* In the axil of the bract, a flower is produced. The flowering shoot is produced in most plants in a definite season known as the *flowering* season and it withers after the production of seeds. There are a few plants like *Hibiscus* and *Thespesia* where separate flowering shoots are not found. The flower arises singly in the axil of the leaf of an ordinary leafy shoot and this type is not common. Flowering shoots may be unbranched or may be repeatedly branched. When a flowering shoot is branching, the main axis of the flowering shoot is called *primary peduncle* and the branch-peduncles springing from it are known as *secondary peduncles.* Sometimes the branching may be repeated further.

Two Types. The different kinds of inflorescence can be arranged under two main types, (1) *Racemose or indefinite* type and (2) *Cymose or definite* type. The two types differ in one important respect and they can be easily distinguished

one from the other. The chief point of difference lies in the capacity for indefinite and persistent activity of the terminal

1 2

Fig. 100. Types of Inflorescence : 1. Racemose (Caesalpinia); 2. Cymose (Ipomaea carnea).

growing point of the peduncle. The same difference which is noticed between the monopodial and sympodial branching is noticed here also. In the racemose type, **the terminal growing point of the flowering shoot is dominant and persistent and continues to be active indefinitely.** Hence, new flowers continue to appear in quick succession one after the other and a cluster of flowers is produced. Owing to this capacity to produce numerous flowers, the racemose inflorescence is also called *Indefinite inflorescence* and it corresponds to the monopodial branching of the shoot. Persistent and indefinite activity may manifest itself in many ways. It may show itself in the growth in length or bulk of the peduncle and it is always indicated by the continuous appearance of new flowers one after another in close succession near the terminal growing point. A characteristic feature

mose cluster is that the flowers lower down are older and open earlier while those nearer the top of the axis are younger. If the axis has grown in bulk, the flowers will be placed close together. The outer flowers will be older and the younger flowers will appear very near the centre. In the cymose type, **the terminal growing point ceases to persist and is itself used up in the formation of a flower first of all.** The axis can thus show no further growth. It can carry only one flower at the very end and hence the cymose type is called *definite inflorescence.* A cluster of flowers will not be possible under the cymose type unless the peduncle is branching. The branching cyme corresponds to the sympodial branching of the shoot and the cymose nature of the cluster is easily recognised by the central or inner flower being always older than the outer flowers. There are different kinds of racemose and cymose types.

I. **Racemose type.** (a) Unbranched: An unbranched racemose inflorescence may be :—

(1) *Typical Raceme.* There is a central slender peduncle which continues to elongate and which produces on its sides

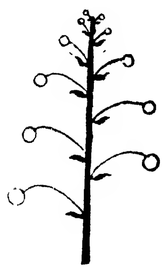


Fig. 101. Typical Raceme.

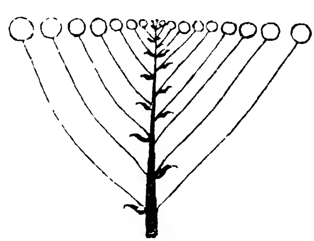


Fig. 102. Corymb.

in the axils of bracts pedicellate flowers one after another in acropetal succession (from below upwards), e.g., *Caesalpinia.*

(2) *Corymb.* This has a central slender peduncle which ontinues to elongate and which produces on its sides in the ; of bracts pedicellate flowers one after another in acro- ı. Here the pedicels of the lower older flowers

show a marked tendency to become long and consequently all the flowers are in the same level and form a flat top, e.g., *Cassia auriculata.*

(3) *Spike.* This shows a peduncle of the same nature as that in a typical raceme but here it carries on its sides in

Fig. 103. Spike : 1. Rungia ; 2. Diagrammatic form.

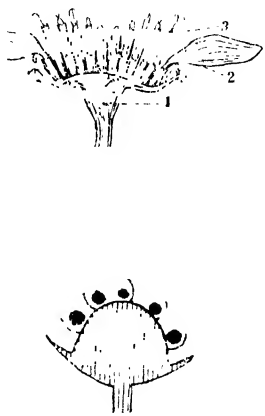


Fig. 104. Capitulum or Head. a. Head in section : 1. Receptacle, 2 and 3. Flowers ; b. Diagrammatic form.

the axils of bracts *sessile* flowers. The flowers therefore do not stand out. e.g. *Rungia* and *Achyranthes.*

(4) *Head or Capitulum.* Here the peduncle grows in length for a time and then its top portion dilates and continues to increase in bulk. On this dilated bulky top, known as *Receptacle,* **small sessile flowers** are produced in the axils of bracts and the flowers are crowded together so as to form a compact cluster. The outer flowers are older while younger flowers continue to appear towards the centre. The bracts are also crowded together and in several forms the outer bracts may not subtend flowers. In a head, therefore, the receptacle

shows numerous bracts crowded together at the lower part and flowers are arranged on the extended upper part. The cluster of bracts at the base of the receptacle is called *involucre* which gives protection to the tender flowers, e.g., *Helianthus* (Fig. 104) and *Acacia.*

(5) *Umbel.* Here the peduncle grows in length for a time but afterwards it does not show a tendency to grow any further in length or bulk. But its terminal growing point is indefinitely active and the axis continues to produce very near the terminal point a large number of pedicellate flowers in the axils of bracts. A number of pedicellate flowers arises in a cluster from very near a common point on the top of the peduncle in the axils of bracts. The outer flowers are older and new flowers make their appearance near the centre. There is an involucre of bracts at the top of the peduncle, e.g., *Calotropis.*

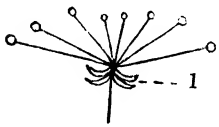


Fig. 105. Umbel : 1. Involucre.

(b) *Branching :* The peduncle may become branched and flowers may be borne on secondary peduncles. Such an inflorescence is known as a compound inflorescence and the type of compound inflorescence can be found by observing the arrangement of secondary peduncles on the primary peduncle and by observing the arrangement of flowers on the secondary peduncle.

(1) *Compound Umbel.* A common form of compound inflorescence is the *compound umbel* as in *Coriandrum.* The primary peduncle produces near a common point on its top a cluster of secondary peduncles each of which carries in its turn from near a common point on its top a number of pedicellate flowers in the axils of bracts. A cluster of bracts is usually given at the point of

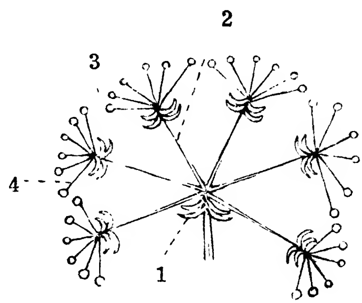


Fig. 106. Compound umbel : 1. Primary peduncle with involucre ; 2. Secondary peduncle ; 3. Flowers ; 4. Pedicel.

origin of the secondary peduncles and also at the point of origin of the pedicellate flowers on each secondary rachis. The chief cluster of bracts on the primary peduncle is called *involucre* and the smaller cluster on the secondary peduncle is known as *involucel.*

(2) *Panicle.* A big cluster is produced when the branching of the peduncle is repeated to a varying extent as in the Mango and Drumstick. Such a repeatedly branching race-

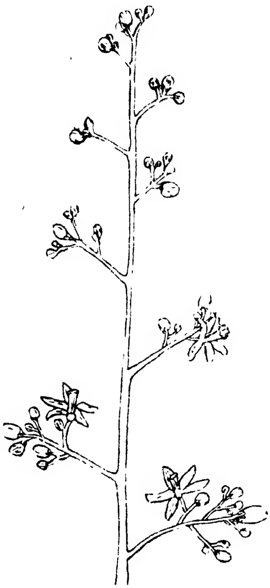


Fig. 107. Panicle.

Fig. 108. Hibiscus.

mose cluster is called a *Panicle* and this term is usually applied to any repeatedly branching inflorescence.

II. **Cymose type.** (a) Unbranched cymes: The unbranched cymose type may be as follows:—

(1) *Solitary terminal.* A simple cyme is one where the upper part of a shoot serves as the peduncle and ends in a flower. No more flower is produced on this peduncle and this form is called *Solitary terminal* as in the Poppy. In the Poppy the upper part of the leafy shoot serves as a peduncle and ends in a single flower.

(2) *Solitary Axillary.* Here, the peduncle is placed in the axil of the leaf of an ordinary shoot as in *Hibiscus.* This peduncle ends in a single flower and the articulation seen on the peduncle a little above the middle shows that the part above the articulation may represent the pedicel of the flower. This is also a solitary type but, on account of its position in the axil it is called *Solitary Axillary.*

(b) *Branching Cymes.* In simple cymes there is no clustering of flowers. But cymose clusters are frequently seen in nature and they arise from the cymose branching of the peduncle. The peduncle ends in a flower and owing to the cessation of the activity of the terminal bud, the axillary buds develop into secondary peduncles which in their turn end in flowers. This tendency may be repeated at regular intervals and a big spreading cluster can be formed, the central or inner flowers being always older than the outer flowers. The form of the cymose cluster will depend upon the number of branch peduncles produced at each stage.

(1) *Simple Cluster.* This type is one where three flowers arise side by side and the central flower is the oldest.

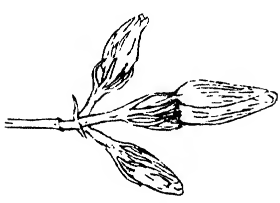


Fig. 109. The Jasmine.

In the Jasmine, the upper part of the leafy shoot becomes the peduncle and its terminal point ends in a flower which is therefore the oldest. In the axil of each of the two small leaves or bracts found near the terminal flower a bud is present which later on develops into a flower. It may be presumed that the axillary bud does not produce any secondary peduncle worth mentioning but it gives rise to a flower. Hence the three flowers are on the same level and the cluster is due to the branching of the axis.

(2) *Dichasial Cyme.* This is a very common form seen in *Ipomaea carnea* and *Clerodendron.* The primary peduncle ends in a flower and close to the terminal flower are seen two small bracts opposite to each other. A bud is laid down in the

axil of each of these two bracts and it develops into a secondary peduncle ; and thus there are two secondary peduncles one on each side of the terminal flower. Each secondary

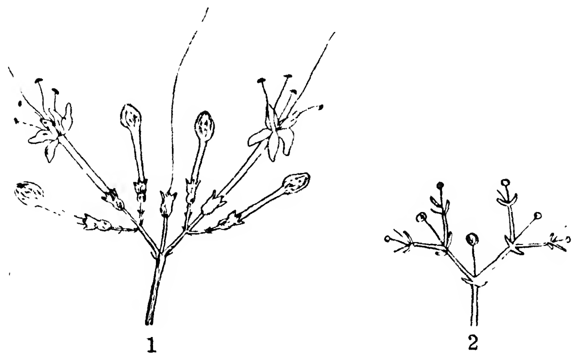


Fig. 110. Dichasial cyme : 1. Clerodendron ; 2. Diagrammatic form.

peduncle ends in a flower and carries in its turn two bracts close to it. As before, two smaller peduncles develop and these end in flowers. Thus the tendency is repeated and branches are produced in pairs at each stage. The inflorescence is presenting a spreading and forked appearance and this form is called *Dichasial cyme.*

(3) *Polychasial Cyme.* This is seen in *Mollugo.* The principle is the same as in the dichasial cyme but instead of two branch-peduncles being produced at each stage, three or more may be given. In *Mollugo* (Fig. 61), the leaves are radical and a number of flowering shoots grow erect. Each peduncle ends in a flower and from the axils of each of the three bracts close to the central flower a secondary peduncle is given. These three secondary peduncles end in their turn in flowers and again three branch peduncles are given. In polychasial cymes there is a tendency for the number of branch peduncles to be reduced to two or even one at a later stage.

(4) *Monochasial Cyme.* This form agrees in principle with the dichasial and polychasial types but **branch-peduncles arise singly at each stage.** The inflorescence will not be spreading. There are two varieties of the monochasial type.

(i) *Monochasial Helicoid.* The primary peduncle ends in a flower and a single bract is seen close to the terminal flower. The bud in the axil of the bract grows into a secondary peduncle which ends in a flower. A bract is produced close to the second flower on the secondary peduncle on the same side as the first bract. The bud in the axil of this bract grows into a branch peduncle which ends in a flower as before. This branch peduncle carries a bract on the same side

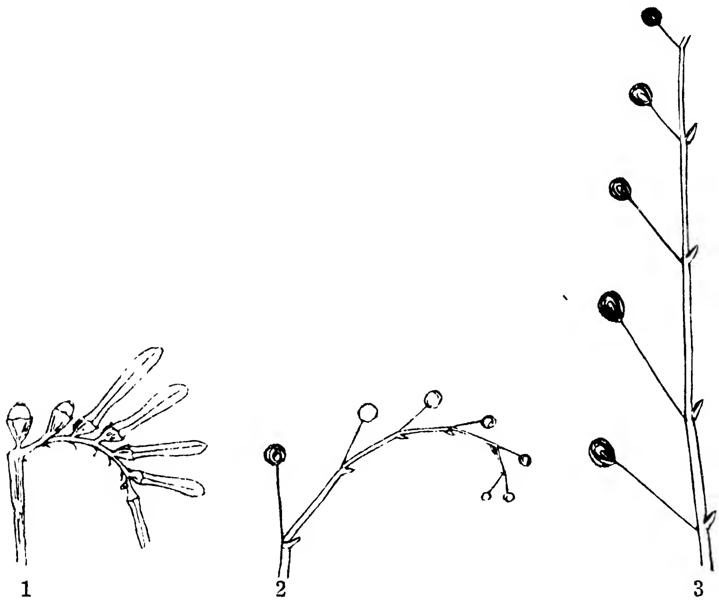


Fig. 111. Helicoid cyme : 1. Hamelia ; 2. Early stage ; 3. Later stage.

as the bract laid down previously and the process is repeated. In the early stage the inflorescence will present a coiled appearance. Since branch-peduncles develop singly at each stage, and since all the peduncles are produced on the same side, the inflorescence resembles the helix or watch-spring, and it is known as *Monochasial Helicoid.* As the inflorescence grows, the successive branch-peduncles grow together to become a continuous jointed central axis. Then the successive terminal flowers are found to be arranged all on one side of this axis while the bracts are placed on the other side,

one opposite to each flower. The lower flowers may appear older but the inflorescence is easily recognised as cymose because all the flowers are on one side and the bract is placed opposite to the flower. *Hamelia,* a plant common in gardens, has polychasial cymes which become reduced to the dichasial form at first and later on to the monochasial helicoid type.

(ii) *Monochasial Scorpioid.* Here also the primary peduncle ends in a flower and a bract arises close to this flower. The bud in the axil develops into a secondary peduncle which ends in a flower. This secondary peduncle produces a bract not on the same side as the first bract but on the opposite side.

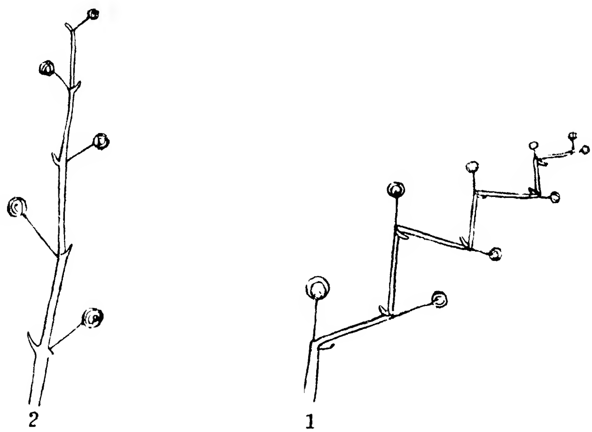


Fig. 112. Scorpioid cyme : 1. Early stage ; 2. Later stage.

This is an important difference which results in a different appearance of the inflorescence. The bud in this axil develops into a branch peduncle which ends in a flower. This branch peduncle carries a bract not on the same side as the second bract. This process is repeated. The inflorescence is monochasial no doubt but it presents in the early stage a crooked, zigzag, appearance owing to the production of branch-peduncles on different sides. As the inflorescence grows, the branch peduncles form a continuous jointed axis and the flowers appear to arise on the sides of this axis. The flowers are not all of them on the same side as in the helicoid cyme. This form is more easily mistaken for a raceme since the older

flowers are found lower down. But as in the helicoid type, the bract is always found opposite to the flower and this is a clear indication of the sympodial or cymose type. *Heliotropium* is a good example of this form. The polychasial cyme of *Mollugo* becomes reduced to dichasial and monochasial scorpioid forms at later stages.

Fig. 113. Ocimum (Thyrsus): 1. Thyrsus ; 2. Two clusters.

III. **Mixed inflorescence.** A branching or compound inflorescence may sometimes combine the racemose and cymose principles. Thus you may get mixed types which are not common. One form that is seen in plants like *Ocimum* may be mentioned and the mixed form in this plant is known as *Thyrsus*. There is the primary peduncle which continues to produce secondary peduncles in pairs at intervals in the axils of bracts. Each secondary peduncle produces a simple cymose cluster of three flowers, the central one being older than the lateral ones. The arrangement of secondary peduncles

is of the racemose type while the arrangement of the flowers on each secondary peduncle is of the cymose type.

SUMMARY

Flowers are usually borne on special branch shoots known as *Flowering shoots.*

The flowering shoot carries small reduced leaves known as bracts in whose axils flowers are produced.

There are two principal types of inflorescence, the Racemose and the Cymose. A third type which combines the features of the two types is also met with.

The peduncle may be simple or branched and flowers usually occur in clusters.

There are several kinds of arrangement in each type of inflorescence.

CHAPTER VIII

THE FRUIT

What it is. Observe the old inflorescence or cluster of flowers of the Drumstick plant. You will see that the parts of flowers are beginning to fall. Perhaps the sepals, petals and stamens have done their work and are no longer required. You see a number of tender fruits, one in each flower. Examine a tender fruit and you will find it corresponds to the ovary. The style and the stigma have also disappeared and the so-called fruit is seen to be merely the developing ovary. In the flower, the ovary is very small and delicate but it has now become considerably enlarged. Fertilisation which takes place inside the ovule exercises a stimulating influence on it and also on other structures closely associated with it. The ovule develops into the seed and the ovary inside whose chamber the ovules are ripening is also stimulated to develop vigorously. Hence after fertilisation has taken place, the ovary begins to develop rapidly and shows great changes in size, form and structure. A fruit is nothing more than the ovary which has been stimulated to develop along different lines by the process of fertilisation and has been altered in various ways. What is called *fruit* in common language is merely the *altered developing ovary* of a flower; and fruits which are made up of only the ripening ovary of a single flower are called *true simple fruits*. Most of the fruits like the Mango and the Lady-finger are of the true simple type.

The term " fruit " is often used in a wide sense to include certain types which consist of an extra part in addition to the ripe ovary of a flower. This extra part is also stimulated by the process of fertilisation and it begins to develop and persist along with the fruit proper. Such fruits which, in addition to the ripe ovary, consist of an accessory part developing with the ripe ovary and persisting with it so as to form part of the fruit are known as *False fruits*. Take the case of the Cashew-

nut fruit. The brown kidney-shaped thing which is mistaken for the seed is seated on a coloured fleshy body. The seed can never be found outside the fruit and the fruit proper is repre-

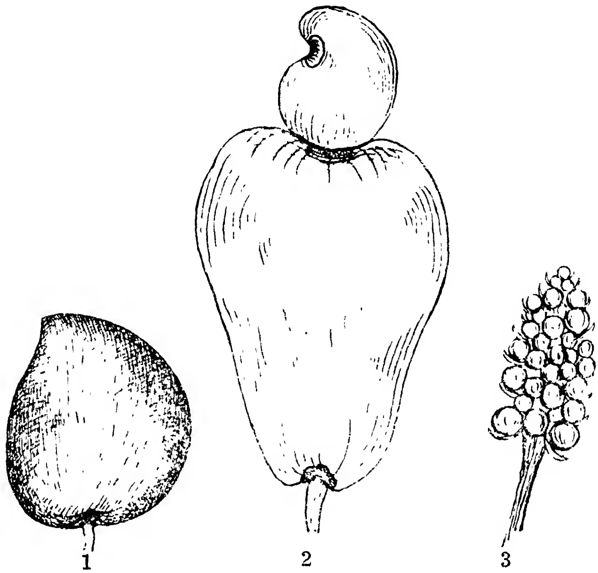


Fig. 114. Types of fruits : 1. True simple fruit (Mango); 2. False fruit (Cashewnut); 3. Collective fruit (Lantana).

sented by the kidney-shaped brown hard body itself. The lower portion which is taken to be a fruit on account of its fleshy and coloured nature is easily proved to be the swollen flower-stalk. The flower-stalk is at first slender and it is stimulated along with the ovary. It also goes on developing side by side with the ovary and finally becomes a coloured fleshy body on which the ripening ovary is placed. The extra part in this false-fruit is thus the flower-stalk. Other parts of the flower like the thalamus and the perianth may also, in rare cases, develop and persist in the fruit.

The term " fruit " is sometimes used in a still wider sense in connection with fruits of the Jack type. In certain cases a bunch of fruits is obtained and the fruits in the bunch may be closely crowded together so as to form a single

compact structure. This bunch is not derived from one flower and hence it cannot be regarded as a true simple fruit. When the bunch is examined carefully, it is found that it is derived from the close crowding together or packing together of the ripening ovaries of numerous flowers arranged in a massive head. A compact fruit derived from an inflorescence is termed a *multiple or collective fruit*. *Lantana* which occurs commonly as a hedge plant, has short axillary spikes and the small flowers are crowded together on a short axis. The hard fruits of the numerous flowers are close together and form a bunch and this is really therefore a collective fruit. That the ovaries belong to different flowers is made clear by the presence of the bract below each small fruit. A bunch formed from an inflorescence should be distinguished from a bunch arising from the apocarpous pistil of a single flower as in *Polyalthia* and *Anona*. The Jack fruit is a collective fruit derived from the inflorescence of pistillate flowers. Numerous pistillate flowers are produced on the surface of a swollen receptacle in the Jack fruit and inside each flower a small fruit is formed. The perianth of each flower also persists and becomes fleshy and it encloses the small fruit inside. All the flowers are now firmly held together and the fruits of the numerous flowers along with the fleshy perianth go to form the Jack fruit. Because the so-called compact fruit is derived from the inflorescence, it should be called *Collective fruit* and there is the additional peculiarity that the perianth of each flower also persists as a fleshy body in the Jack fruit.

Parts of the true simple fruit. Since the ovary of the flower ripens into a fruit, the parts of the ovary are seen in an altered form in the true simple fruit. The wall of the ovary becomes the wall of the fruit and the chambers of the ovary persist as the chambers of the fruit. The ovules of the ovary ripen into seeds in the fruit. A true simple fruit thus consists of a wall known as *pericarp* which encloses one or more chambers inside which seeds are ripening.

Changes in the ovary. The changes which the ovary undergoes while ripening into a fruit are interesting. The

wall is variously altered and it becomes thick and juicy in most cases and gives a fleshy appearance to the fruit. It also acquires *colour* as it is ripening. Fruits where the pericarp becomes fleshy are known as fleshy fruits. In several cases the wall may gradually lose water and finally become dry. Fruits where the pericarp becomes dry are known as

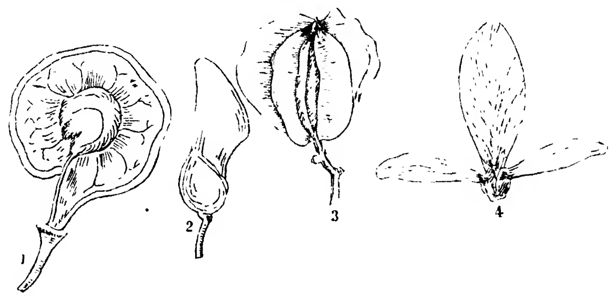


Fig. 115. Winged fruits : 1. Pterocarpus ; 2. Pterolobium ; 3. Combretum ; 4. Hiptage.

dry fruits. The dry wall may be thin and membranous ; and sometimes the membranous pericarp may be flattened out all along or at certain points into fine wings as in *Pterocarpus* and *Combretum.* Fruits which show wing-like extensions are called *winged* fruits. In a few cases, the pericarp may become hard and woody as in the kidney-shaped brown part of the Cashewnut. The number of chambers may continue to be the same in the fruit or may be reduced during the ripening. In a few cases false partitions may arise as in *Cassia fistula* and *Ipomaea* and the number of chambers may be increased.

Fleshy fruits. (1) *Berry.* This is one-or more-celled, one-or more-seeded fruit in which the pericarp is more or less completely fleshy except for a thin skin towards the outside. The pulp fills up the chambers of the fruit and the seeds are embedded in it. The fruit of *Psidium* (Guava) is a many-celled and many-seeded berry and the seeds have hard coats. The grapes are berries containing a few seeds and the outer portion of the pericarp is in the nature of a skin or membrane. Some variations from the normal type are also

seen. The orange is not far different from a berry but the pericarp is not uniformly fleshy. There is a tough rind towards the outside followed by a papery membrane and the fleshy part consists of a number of spindle-shaped juicy processes piled up one over the other. The Wood-apple is so called because the fleshy pericarp is differentiated into a hard woody layer towards the outside.

(2) *Drupe or Stone-fruit.* This is usually an one-celled, one-seeded fruit in which the pericarp is differentiated into three different layers. The outermost layer is a thin membrane or skin known as *epicarp*; the middle region is pulpy and is known as *mesocarp*; and the innermost layer enclosing the seed is a hard stone and is called *Endocarp*. It is on account of the innermost stony layer that the fruit is called the stone fruit in common language. The development of the

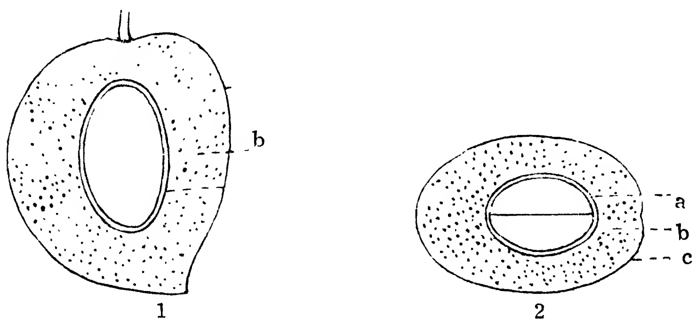


Fig. 116. Mango: 1. L. S., 2. C. S.; a. Endocarp; b. Mesocarp; c. Epicarp.

stone is a constant feature of the drupe. The stone encloses the chamber in which the seed ripens. The Mango is a typical drupe. There are certain drupes which are many celled and show more than one stone; and inside each stone is found a seed as in the Palmyra. The fruits of *Phyllanthus emblica* are three-celled with three stones. In multi-locular drupes, each stone with the seed inside is called a *pyrene*. The *Coconut* shows some of the chief features of a drupe and the stone inside is very hard.

These fleshy fruits do not open to let out the seeds which can come out only after the decay of the pericarp.

Dry fruits. Dry fruits have a pericarp which will show no trace of flesh or pulp anywhere. It is membranous or hard. Dry fruits are of two kinds according as they open or not. Dry fruits that do not open of their own accord when ripe are known as *Dry indehiscent fruits.* Many of the dry fruits split of their own accord and the seeds are let out. Such fruits are known as *Dry dehiscent fruits* and some of these forms are also known as *pods.* In the case of the dry indehiscent fruits, the seeds can come out as in the case of fleshy fruits only after the decay of the pericarp.

(a) *Dry indehiscent fruits.* (1) *Achene.* This is a small one-celled, one-seeded fruit the pericarp of which is not very tough. This pericarp is closely applied to the seed but not united with it, e.g., Sunflower.

(2) *Nut.* This is an one-celled, one-seeded fruit, the pericarp of which is uniformly hard. The fruit proper of the *cashewnut* found on the fleshy pedicel is a *nut* because the pericarp is uniformly hard. You may have heard of the Chestnut and the Hazelnut. A nut is supposed to be really derived from a multi-locular ovary but only one chamber manages to develop well.

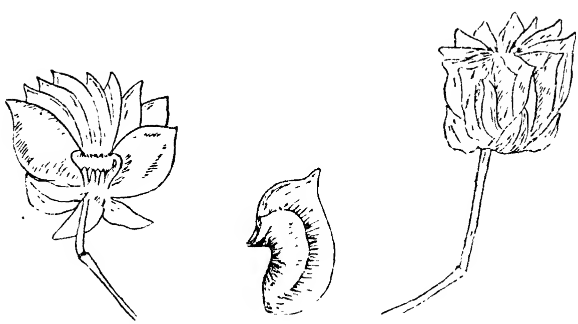


Fig. 117. Schizocarp : 1. Fruit of Abutilon ; 2. Fruit opening ; 3. A Coccus.

(3) *Schizocarp.* This kind of fruit is not completely indehiscent. When it is ripe, it splits but the seeds are not exposed. This is derived from a multi-locular ovary.

When it is ripe, it opens in such a way that the several chambers come off as independent closed segments and fall off. Each segment which is still a closed chamber containing seeds is called a *Coccus* and the entire fruit where dehiscence results merely in the separation of the chambers is called *Schizocarp*, e.g., *Abutilon.*

Fig. 118. Legume of Pithecolobium dulce.

(b) *Dry dehiscent fruits.* (1) *Legume.* This is a flat fruit derived from a monocarpous pistil. It splits lengthwise along both the dorsal and ventral sutures and there are thus formed two long pieces or valves. These valves may in certain cases suddenly roll themselves up into a spiral and the seeds are scattered, e.g., *Pithecolobium, Phaseolus* (Pulses), and the Pea.

(2) *Follicle.* In a cluster of fruits formed from an apocarpous pistil or apocarpous-like pistil where a number of free ovaries is seen, each bit opening only along the ventral suture is called a *follicle.* Every ripe ovary in the

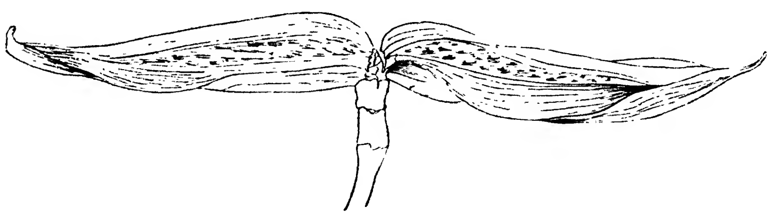


Fig. 119. Two Follicles of Cryptostegia.

group splits lengthwise separately along its ventral suture alone. Hence only one valve is formed and the seeds are thrown out. Thus the follicle generally occurs in clusters and

each bit in the cluster is the product of one carpel. *Calotropis* and *Vinca* are plants where two distinct ovaries are present. These can ripen into two fruits each of which is formed of only one carpel. Each fruit opens separately along the ventral suture and forms a follicle. *Sterculia* has a deeply five-lobed ovary and the lobes appear distinct at the ripe stage. Each lobe opens along the ventral suture and a cluster of five follicles is seen.

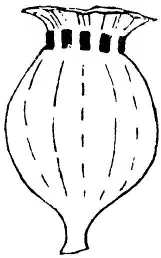


Fig. 120. The Poppy fruit.

(3) *Capsule.* This is a very common type of fruit of which there are several kinds. It is derived from a syncarpous pistil. Except in a few cases, the capsule splits lengthwise at definite points into a number of pieces known as valves and the seeds are sent out.

(a) *Porous capsule.* This is a capsule derived from a syncarpous pistil with a uni-locular ovary as in the Poppy. A number of fine holes appears at the neck of the capsule through which the seeds come out.

(b) *Toothed capsule.* This is a capsule derived from a syncarpous pistil with a uni-locular ovary as in the Mexican Poppy (*Argemone*). The dry fruit gives way slightly at the top and through the slits between the teeth, the seeds are jerked out. In these two kinds the capsule does not split lengthwise.

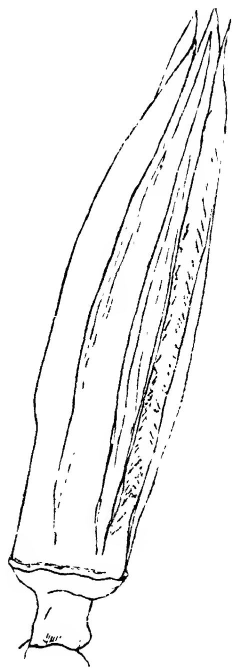


Fig. 121. Hibiscus : (Loculicidal capsule).

(c) *Loculicidal capsule.* This is a fruit formed from a syncarpous pistil with a multi-locular ovary. Here dehiscence takes place along the dorsal suture of each chamber and it extends from the base to the top. As a result, valves are

formed and their number is the same as that of the chambers of the ovary and each valve is more or less boat-shaped with one of the partitions running along the middle. On account of the dehiscence occurring along the dorsal side, the loculus

2 1 3 4

Fig. 122. Dehiscence of the Capsule : 1. Loculicidal ; 2. Septicidal ; 3. and 4. Septifragal.

or chamber of the fruit is cut open and the dehiscence is known as loculicidal dehiscence. The capsule dehiscing in this manner is known as *loculicidal capsule.* As the valves are formed, the chambers are exposed and the seeds come out, e.g., *Hibiscus esculentus* and *Gossypium.*

(d) *Septicidal capsule.* This is formed in the same manner as the loculicidal capsule but it opens in quite a different way. Every partition in the ovary separating one chamber from another is split lengthwise along the plane of the union of the two adjoining infolding carpellary edges. The two infolding edges which together form the partition are thus separated and consequently a number of valves equal to the number of chambers present in the ovary is formed. Each valve is thus standing for a complete chamber and the dehiscence along the septum has merely resulted in the detachment of the chambers as independent segments. This capsule is therefore called septicidal capsule which is, strictly speaking, a Schizocarp. Septicidal dehiscence does not lead to the scattering of seeds immediately as in the case of loculicidal dehiscence, e.g., *Abutilon* and the Castor.

(e) *Septifragal capsule.* This is a capsule which may open either loculicidally or septicidally. But the wall of the fruit tears away from the rest of the fruit so that the seeds are exposed and scattered, e.g. *Datura.*

Aggregate fruit. In the flowers of *Polyalthia* and *Anona*, the gynœcium is apocarpous and you see a cluster of small pistils. While the small pistils of the cluster are completely free from one another in *Polyalthia* they tend to cohere in *Anona*. All these pistils of the cluster ripen and you get a cluster of fruits. The bunch belongs to a single flower and cannot be regarded as a collective fruit. It is common to regard such clustered fruits derived from the apocarpous pistil of a flower as *Aggregate fruits*. In *Polyalthia* the numerous berries of the cluster are independent and remain separately attached by short stalks to the top of the pedicel. In the aggregate fruit of Anona, you can see the bits representing the several pistils. But during the development of the fruit, the thalamus which accommodates the numerous pistils, persists and becomes very fleshy. The pistils which arise on the thalamus happen to be embedded in the fleshy development of the thalamus and the fruit is a compact fleshy body.

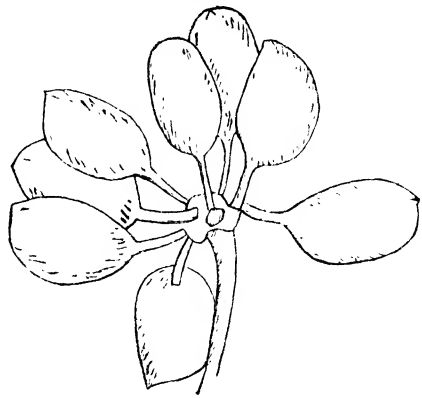


Fig. 123. Polyalthia : Aggregate fruit.

False fruits. The Cashewnut along with the swollen pedicel forms the false fruit. There are other plants which produce false fruits. The extra part may be morphologically different. The Apple and the Pear are false fruits, though they look like drupes. These two fruits are fleshy. There is a skin towards the outside and this is followed by a massive pulpy tissue. Further inside, is seen a five-chambered structure containing seeds. The layer enclosing the chamber is rather hard so that the fruit

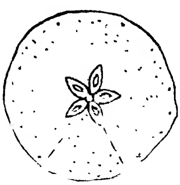


Fig. 124. The Apple : 1. The ripe ovary ; 2. Thalamus.

is likely to be mistaken for a drupe with pyrenes. The core of the fruit consisting of the hard structures is, on observation, clearly seen to be the entire pistil of the flower. Hence the fleshy tissue surrounding the hard core is not a part of the wall of the ovary but is really a portion surrounding the entire ripening ovary. It is therefore the thalamus itself which has developed into a fleshy structure around the ovary. Hence the Apple and the Pear are false fruits.

Collective or multiple fruits. These are derived from an inflorescence. *Lantana* and *Artocarpus* (Jack) show collective fruits. In the jack-fruit, there are several areas recognised on the outer surface of the fruit with a minute protru-

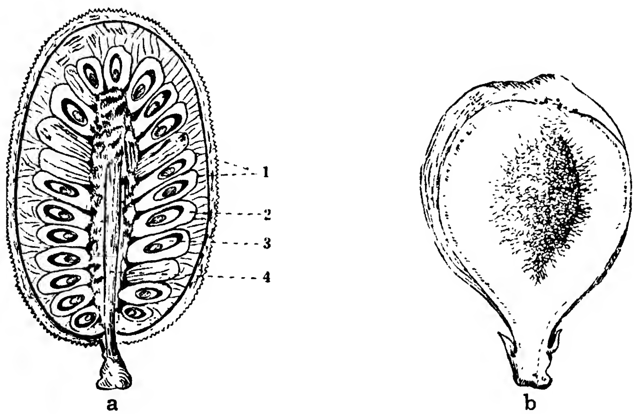


Fig. 125. Collective fruits : a. The Jack : 1. Pistillate flowers ; 2. Perianth of the same ; 3. Ripe ovary with seed ; 4. Receptacle ; b. The Fig.

sion in the centre of each area. Each area stands for a pistillate flower and the protrusion is the style proceeding from the ovary. The persistent perianth which is edible appears fleshy. The Fig may be regarded as a kind of collective fruit. Here the minute uni-sexual flowers are arranged on the inner surface of the hollowed out peduncle. The receptacle inside which the flowers are found, becomes very fleshy and the numerous little fruits which are embedded in the pulp and look like tiny seeds are really achenes.

SUMMARY

The term " Fruit " is used in different senses. Fruits may be spoken of as true simple fruits, false fruits and collective fruits.

The fruit is the ripening ovary of a flower which is stimulated to grow along definite lines as the result of fertilisation of the ovule.

The ovary becomes variously altered and the fruit will be fleshy or dry.

There are different kinds of fruits; and dehiscent fruits open of their own accord when ripe and let out the seeds.

CHAPTER IX

THE SEED

Formation. The seed is a very important structure helping the reproduction of flowering plants on a large scale. It may be regarded as the direct result of fertilisation and its formation is bound up with the process of fertilation. The seed may be roughly considered as the fertilised ovule and many of the parts present in the ovule can be still recognised in the seed though in an altered form. The ovule is attached to the placental outgrowth on the wall of the ovary by a stalk or *funicle.* The body of the ovule is at first small and arises as a small protuberance. At an early stage it consists of a small mass of young cells and this group is called *Nucellus.* This nucellus is soon covered by two coverings arising near the base of the ovule one after the other and extending gra-

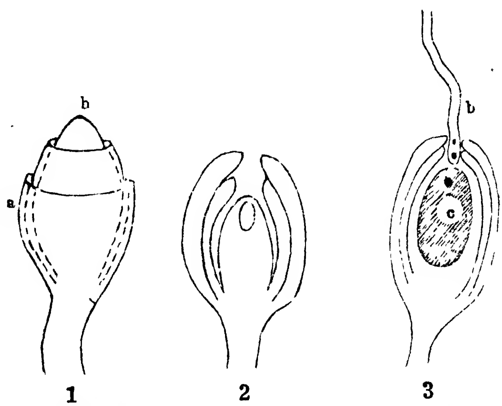


Fig. 126. Young ovule : 1. Early stage : a. Integument, b. Nucellus ; 2. Later stage ; 3. Ovule ready for fertilisation : a. Integuments, b. Pollen-tube passing through the micropyle, c. Embryo-sac.

dually over the nucellus. The two coverings which enclose the nucellus are known as *Integuments.* The two integuments do not close up at the free end of the ovule and there is therefore left a minute canal or passage called the *micropyle* through which the nucellus can communicate with the outside. Changes take place in the nucellus itself and

very soon a big cell with living substance in it becomes very conspicuous near the free end of the ovule. This develops very vigorously and the cells of the nucellus are disorganised. Thus the ovule happens to show two coverings enclosing a big cell which is really a big germ-body or spore produced inside the ovule. Only small traces of the original nucellus can now be recognised in the ovule. This germ-body begins to be active even while inside the ovule and this activity is spoken of as the germination of this body. When it has begun to be active, it is called *embryo-sac,* perhaps because the embryo is going to be produced here. The chief point about the development of the embryo-sac is the differentiation of the *egg* which is a sex-cell. One of the two sperms borne at the tip of the pollen-tube fuses with the egg and this fertilised egg receives the stimulus of fertilisation first of all. The stimulus of fertilisation leads to the development of the fertilised egg into the embryo and also brings about further alterations in the ovule. The ovule thus becomes the seed. The integuments of the ovule become the *seed-coats* of the seed. The micropyle is seen as a minute pore in the seed-coats. The scar on the seed-coat of a ripe seed indicating the attachment to the funicle is known as the *hilum.* The seed ripens gradually inside the fruit and at the ripe stage it loses all traces of water from its body. The ripe seed is therefore dry and hence the embryo inside cannot be active. It passes through a period of inactivity but is keeping alive. Under favourable conditions the activity of the baby plant inside is aroused.

Some seeds. (a) *The Bean seed.* Examine the common Bean seed which has been soaked in water. You notice a skin or covering which can be easily peeled off. This is the seed coat known as *Testa.* You do not see easily the inner covering. Notice the long scar or hilum on the testa. If you press the seed between your fingers, water may ooze out from a minute pore on the testa close to one end of the hilum and this pore is the micropyle. On removing the seed-coat there is left a massive body with a short tapering portion on one side. The massive part is not a single body but

really consists of two similar flat thick bodies standing face to face. If the entire structure inside the seed coat be spread out and examined, there is seen in the centre a short tender axis. One end of this axis is differentiated into the tapering root-like body. This tapering root-like body which is

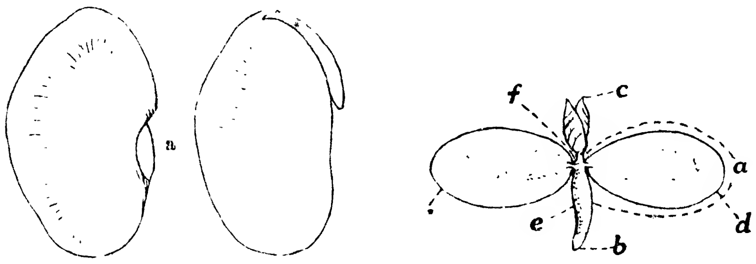


Fig. 127. The Bean seed : 1. Seed with the coat : a. Hilum ; 2. Seed with the coat removed ; a. Radicle ; 3. Embryo spread out ; a. Axis ; b. Radicle ; c. Plumule ; d. Cotyledons ; e. Hypocotyl ; f. Epicotyl.

always directed towards the micropyle is called the *Radicle* which is the rudiment of the root system. At the other end of the axis is to be seen a tiny bud with a few leaves packed together. This is called the *plumule* which is the starting point of the shoot system ; and it is hemmed in between the two thick bodies. The two thick flat bodies which are far bigger than the radicle and the plumule arise opposite to each other on the sides of the axis a little above the middle and these are known as *cotyledons.* From their position on the sides of the axis and from their flat nature, the cotyledons may be taken to be leaf-like structures. These are called seed-leaves in common language and they appear thick owing to the storage of food-materials. In the Bean seed, therefore, the body enclosed by the seed coat has got all the parts of the future plant in a very rudimentary state and **it is to be considered really as a miniature or baby plant.** This rudimentary or baby plant is called the *embryo* and it is the fertilised egg that has developed into this embryo. The seed is useful for propagation because of the presence of the embryo and the embryo is undoubtedly the most important part of a seed. The seed-coat serves to protect the embryo and it is very interesting to see that the food-materials needed for the development of the tiny embryo should be kept in a part of its own body, the cotyle-

dons. The seed-leaves or cotyledons are the store-houses of reserve materials in the Bean seed. It will be necessary to examine other seeds in order to understand the variations in structure.

(b) *The Pea and the Pumpkin.* The Pea seed shows much the same structure as the Bean. Examine the seed of the Pumpkin. It is a flat seed narrow at one end and broad at the other end. It is attached at the narrow end and the micropyle and hilum are to be noticed here. There is the tough testa towards the outside and on removing this, there is noticed a grey membrane closely applied to the inner mass. This membrane represents the inner seed-coat called *tegmen* which is easily separated from the inner mass. The mass inside is the embryo and it shows the short tapering rod or the radicle close to the narrow end and the plumule at the other end is minute. The two cotyledons are large and thick and arise on the central axis.

(c) *The Castor seed.* The Castor seed is more interesting. It is also somewhat narrow at one end and broad at the other end. At the narrow end is seen a fleshy outgrowth called *caruncle* concealing the micropyle and hilum. The hard shell-like coat is the testa. Inside the testa is seen a thin white papery membrane which is in close contact with the inner mass and this is the tegmen. Immediately inside the tegmen is seen a pulpy mass. If the pulpy mass be removed

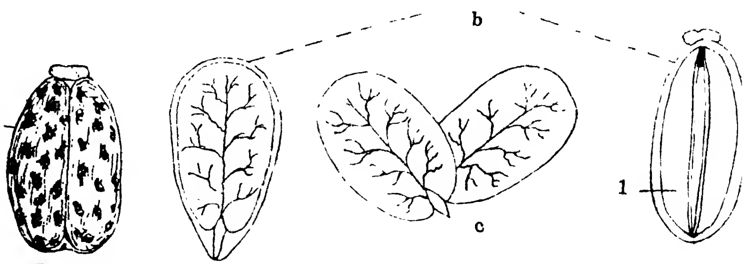


Fig. 128. The Castor seed : a. Ripe seed ; b. Seed cut longitudinally in different planes : 1. Endosperm ; c. Embryo.

bit by bit, the embryo is clearly seen. The radicle and the plumule are minute as in the Pumpkin and the cotyledons are

two in number as in the previous types. But the cotyledons are peculiar because they appear as thin, flat, blade-like structures with veins traversing them. That the cotyledons are leaves in their nature is made plain by the Castor seed and their thin leafy nature shows that they do not function as store-houses as in the case of the Bean seed. Where is the provision in the Castor seed for food materials which the embryo needs ? The embryo is surrounded by the fleshy mass which intervenes between the seed coats and the embryo. This mass is rich in material and it contains plenty of oil. The store-house in the Castor seed does not form part of the embryo itself as in the Bean but it represents a separate tissue developing outside the embryo but inside the seed. This special reserve tissue of the seed outside the embryo is called *Endosperm* and such a tissue does not exist in the Bean, the Pea and the Pumpkin. Seeds where there is no endosperm developed are described as *Exalbuminous seeds* and the cotyledons of the embryo in such seeds act as store-houses of materials. Seeds of the Bean and the Pea are exalbuminous. Seeds where endosperm is developed, are known as *Albuminous seeds* and here the cotyledons are thin. The Castor seed is a good type of albuminous seed. In all the seeds described above, the embryo is fairly big and possesses two broad cotyledons standing face to face and protecting the plumule. Many are the plants in the embryos of whose seeds two cotyledons are always seen and these are brought together under one group, **Dicotyledons.** The Mango, the Tamarind, the Bean, the Pumpkin and the Castor are dicotyledonous plants. Should the number of cotyledons be two in all plants ? There are several plants like the Onion, the Palms and the Grasses where the embryo of the seed shows only one cotyledon. Plants of this kind are grouped together as **Monocotyledons.** The difference in the number of cotyledons seems to be constant and hence there is a meaning in the division of the ordinary flowering plants into Dicotyledons and Monocotyledons.

(d) *The Maize grain.* The seed of a monocotyledon is somewhat difficult to understand, especially because of the

minuteness of the embryo. Examine the maize grain. This is more or less rounded, the inner portion being somewhat narrow. This grain is really a fruit whose pericarp has fused with the seed-coat to form a common covering. At one of the flat sides close to the inner end is situated the minute embryo which lies by its back against the endosperm.

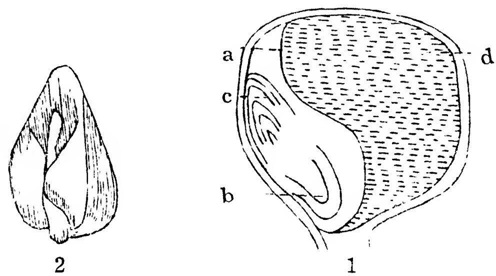


Fig. 129. The Maize grain : 1. Grain in section ; a. Cotyledon, b. Radicle, c. Plumule, d. Endosperm ; 2. Embryo with the sheathing cotyledon.

Towards the outside is the covering of the grain. The bulk of the seed consists of the endosperm which is rich in starch. The axis of the embryo is very minute and the radicle and the plumule cannot be easily recognised with the naked eye. The different parts can be made out easily on examining a section of the grain. There is only one cotyledon which is comparatively big and this lies by its back against the endosperm. This is rather thin and it is sheathing the plumule and the radicle. In the monocotyledons in general, the embryo is minute and club-shaped and the thin cotyledon is the only part that is easily recognised. The remaining parts are made out when a section is examined under the microscope. The single cotyledon which forms the prominent part of the embryo in all monocotyledonous seeds is never flat. It is often rolled into a sheath from one edge to the other and hence you find the embryo as a club-shaped body with the cotyledon sheathing the rest of the embryo. The embryo is not placed at one end of the endosperm in all monocotyledons. In the Coconut palm, (Fig. 130) the minute club-shaped embryo is embedded in the endosperm. The seeds of monocotyledons are mostly albuminous. The common Paddy is

botanically complex. It is a grain like the Maize but the yellow chaffy coverings belong to the inflorescence. Rice is the endosperm in Paddy and the minute embryo is seen in a depression at one end of the grain. This embryo is thrown off in the milling process and what is sold as rice is the endosperm which is rich in starch.

Parts of the seed. The seed consists of (1) the seed coats, (2) the endosperm, and (3) the embryo.

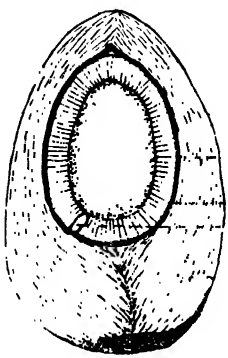


Fig. 130. Coconut in section : 1. Epicarp ; 2. Mesocarp ; 3. Endocarp ; 4. Endosperm ; 5. Embryo.

Embryo. The embryo is the most important part and it remains inactive in the seed. It may be big as in the dicotyledonous seeds of Bean and Castor or may be small and club-shaped as in the Palms and Grasses. It may store food materials in its own body as in exalbuminous seeds or it may depend upon the food materials stored up in a separate tissue as in albuminous seeds. The cotyledons are similar in form and size. In the dicotyledonous embryo, the part of the axis immediately below the cotyledons is prominent and it is called the *hypocotyl* which passes on into the *Radicle.* The part of the axis immediately above the cotyledon is known as the *epicotyl.* The radicle is always directed towards the micropyle and the leaves of the plumule are very tender. The materials stored up in the cotyledons are generally in the form of starch ; and the dholl and the pulses are some instances of seeds of economic value where the cotyledons store up materials. In the albuminous seeds the cotyledon is thin ; and it shows special activity and becomes changed when the seed begins to germinate.

Endosperm. The endosperm is a special reserve tissue of the seed lying close to the embryo and it is not present in all seeds. It may be hard as in the Wheat and Paddy or soft

as in the Castor seed. Sometimes the tegmen penetrates into the hard endosperm at certain points and makes it striated as in the seeds of *Anona* and *Polyalthia.* The endosperm is then described as *ruminate.* The materials in the endosperm may be starch as in rice, or oil as in the Castor and Coconut; and proteins are also found along with the materials mentioned previously.

Seed-coats. The seed-coats are the integuments that have become altered. The outer integument becomes the *Testa* and the inner one becomes the *Tegmen.* The testa is present in all seeds while the tegmen is seen only in some seeds. When the tegmen occurs, it is closely applied to the inner mass and is always seen as a thin membrane as in the Castor and the Pumpkin. The testa may be a tough membrane or a hard shell-like layer. The membranous testa may sometimes be flattened out remarkably so as to give the appearance of a wing and such a seed is known as a winged seed as in *Tecoma* and *Millingtonia.* The testa may, in rare cases, become fleshy as in the Pomegranate. It may have a smooth surface as in the Castor seed or it may be rough and irregular. Different colours are also noticed in the testa and seeds with attractive colours are seen in *Abrus* whose seeds are used as weights by goldsmiths. Outgrowths of different kinds also arise on the testa after fertilisation has taken place. A common form of outgrowth on the testa is the hairy process which may occur all over the testa as in the Cotton seed or may be confined only to one end of the seed. In *Calotropis* the seeds are flat. They are narrow at one end and at the narrow end a fine tuft of hairs is borne. This tuft is called *Coma* and seeds with coma

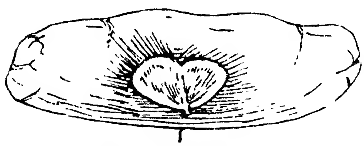


Fig. 131. Winged seed.

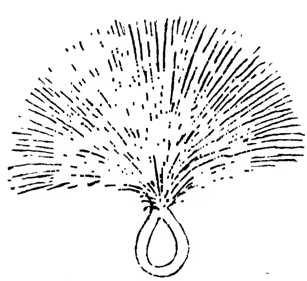


Fig. 132. Comose seed.

are described as *Comose.* More prominent outgrowths are sometimes developed around the testa and they may gradually go over the testa and form an additional covering. They may originate from near the hilum or micropyle region. Such a fleshy or membranous outgrowth is generally called *Aril,* whatever may be its size. It may be a small fleshy protuberance as in the Castor seed or a pulpy massive structure as in *Pithecolobium dulce.* The aril of the seed of Water-Lily takes the form of a membranous bag enclosing the seed while the fleshy aril of *Pithecolobium dulce* is sought after by birds which may carry away the seed to distant places. The Nutmeg fruit shows a network of thick and coloured outgrowths round the single seed and this cluster is popularly known as *mace.* This useful spice is only a kind of aril. The seed thus shows several striking differences in form and structure and you may be curious to know whether there is any advantage to the plant in having such seeds.

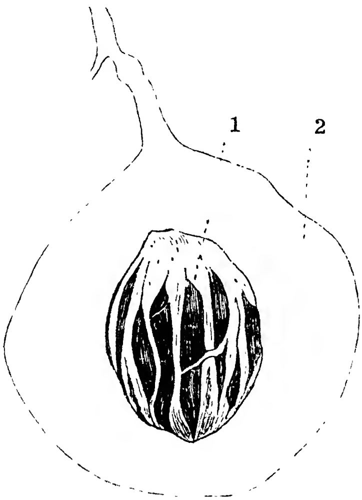


Fig. 133. The Nutmeg fruit : 1. Aril round the seed ; 2. Fruit.

Germination. A ripe seed is more or less dry and in the absence of water, the living substance in the embryo cannot be active. The embryo is thus alive but inactive. The ripe seed does not show signs of activity the moment it becomes free. It has to pass through a short period of " after-ripening " before it is fit to become active. There are cases of seeds which retain their vitality for a long time. Certain favourable conditions are necessary for the awakening of the activity. Under such favourable conditions, the embryo begins to be active and shows signs of growth. The parts of the embryo try to get out of the seed-coat and reach proper positions. There is an appreciable enlargement of the

parts and finally a young plant or seedling is produced. All these stages of growth noticed in the embryo of the seed up to the time of the formation of the seedling constitute the process of *germination* of the seed. The embryo which is at first a minute body has, during the germination of the seed, done good work, and it also shows marked development of the body through definite stages. This activity of the embryo involves the supply of ready made materials since it is not in a position to prepare any material on its own account. You know that there is a store-house in every seed either in the embryo itself or very near the embryo and the materials in the store-house are utilised when it begins its activity.

Conditions for germination. The conditions that are essential for the germination of the seed are (1) Moisture, (2) Oxygen, and (3) Temperature. The dry seed can become active only when it is supplied with moisture. Water enters the seed through the micropyle in the first instance and reaches the embryo. Then the activity of the embryo is awakened and germination begins. Germination can proceed further only when the seed is in contact with the moist layer of the soil. The active embryo requires to be supplied with oxygen and you know that no active living thing can exist in the absence of oxygen. If some germinating seeds be grown in an oxygen free atmosphere, they will die very soon though other conditions are favourable. The ploughing of the soil serves to improve the aeration of the soil. Temperature also exerts an important influence on germination. Temperature, either too high or too low, is very unfavourable and germination goes on vigorously between 25° C. and 30° C. The part that the soil and sunlight play should also be clearly understood. During germination the soil is useful because of the water contained in it. It is possible to let seeds germinate in moist saw dust or in wet blotting paper. Later on, when the seedling is produced, the soil becomes more important. As for sunlight, the process of germination does not directly depend upon it. The formation of a seedling can take place in the absence of sunlight but it will not be healthy. When the seedling is formed, the need for sunlight is felt keenly.

Stages of germination. (a) *The Bean seed.* When the seed is sown in the moist soil, it absorbs water through the micropyle and the water reaches the embryo. The first sign of activity is the swelling of the seed followed by the rupture of the testa. The testa is ruptured near the region of the micropyle in the first place and the radicle which is close to the micropyle and which has become active, protrudes outside the seed-coat and becomes visible. The radicle is the part of the embryo to come out of the seed first of all and it begins to grow down into the soil. In whatever position the seed may happen to be placed, the radicle is seen to grow down. If it be pointing upwards at the time of sowing, it begins to curve down as soon as it has come out and then grows downwards into the tap-root. This tendency to grow downwards is a feature of the root. Meanwhile the seed-coat is ruptured further and it gets wrinkled. The exit of the radicle marks the first stage which is common to all germinating seeds. The second stage is marked by the appearance of the

Fig. 134. Germination of the Bean seed: 1. Tap-root; 2. Hypocotyl arch; 3. Epigeal cotyledons; 4. Seedling.

plumule above the soil. How is this brought out? What happens to the cotyledons? Examine a few Bean and

Pigeon-Pea seeds germinating in the soil. A few days after these seeds are sown, you find fine cracks in the soil through which an arched part is seen to be coming out. Take out a germinating Bean seed and examine the condition at this stage. You will find that the arched part is the hypocotyl region, i.e., the region of the axis just below the two cotyledons. The hypocotyl part which is fixed by the root end to the soil elongates and becomes arched. This arch grows up through the soil. As it grows up it clears the soil immediately ahead of it and thus makes a fine crack. When the hypocotyl elongates, and the arch reaches the surface of the soil, the cotyledons with the plumule in between them borne at the free end of the hypocotyl are gently pulled out of the seed-coat and taken up through the crack in the soil to the surface. Lastly the hypocotyl straightens and the plumule along with the cotyledons is raised above the surface of the soil. Now that the plumule has come up, its leaves begin to unfold one after another. Observe the cotyledons at this stage. They are seen to be shrivelled and the materials in them should have been removed and utilised by the embryo. They appear slightly green but fall away soon when the growth of the plumule begins. There is formed a young plant or *seedling* with a tap-root growing and branching in the soil and a primary shoot growing up in air and light. The seedling is now able to lead an independent life and it often happens that the first set of leaves is different from the leaves that appear subsequently. It may be interesting to know how the tender plumule has been brought up uninjured. This is due to the crack formed previously in the soil by the growing up of the hypocotyl arch. This arching of the axis has thus a mechanical significance and the flat cotyledons along with the flat plumule are brought out through the slit uninjured.

(b) *The Pigeon-Pea seed.* The radicle comes out as before. Here also cracks in the soil are formed and arched portions protrude. The bases of the two cotyledons appear to be slightly pushed apart from each other and the epicotyl manages to protrude outside. If the Pigeon-Pea is pulled up and examined, it is found that the elongating and arching part is not the **hypocotyl** as in the Bean but the **epicotyl,** i.e.,

the part just beyond the cotyledon. When the protruding epicotyl elongates and the arch is growing up, the plumule

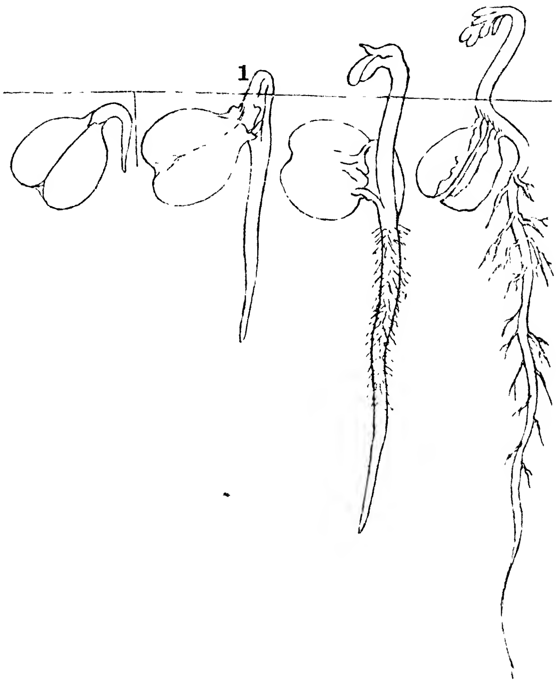


Fig. 135. Germination of the Pigeon-Pea : 1. Epicotyl arch.

which alone is borne at the free end is gently pulled out of the seed coat and brought up to the surface of the soil. The cotyledons are left in the soil inside the seed coat. By the time the plumule has gone up and begun to develop, the cotyledons in the soil become reduced and finally disappear. Here also there is the arching of the axis which serves to bring up the tender plumule uninjured and the plumule is raised above the soil when the axis becomes straight. Owing to the difference in the part of the axis that begins to arch, the cotyledons appear above the soil along with the plumule in the Bean during germination while they are in the soil in the case of the Pigeon-Pea. Germination is described as *Epigeal* in the

former case and the cotyledons are also described as *epigeal.* In the case of the Pigeon-Pea where the cotyledons remain in the soil throughout germination, they are described as *Hypogeal* and germination is termed *hypogeal.* In all exalbuminous seeds the cotyledons are useful merely as store-houses of reserve materials and play no active part during germination. As germination progresses, they become reduced and disappear when the plumule begins to develop. In the Pumpkin, the cotyledons are epigeal and they also turn green.

(c) *The Castor seed.* In the case of albuminous seeds, germination goes on somewhat more slowly. The materials

Fig. 136. Germination of the Castor seed.

found in the endosperm have to be absorbed and carried to the different parts of the embryo. Some specialisation is needed to enable the embryo to absorb the materials from the endosperm and to pass them on to the radicle and the plumule. The cotyledon is the only structure that can be thought of in this connection and it is the cotyledons that play an active role during germination. They may be simple at first but when germination begins, they

become differentiated. This specialisation is not very marked in the Castor seed. Here the first stage is the same as in all seeds. Then, the hypocotyl arch is formed which grows up as in the Bean and makes a slit in the soil. But the plumule and the cotyledons are not brought out immediately. If you take out a germinating Castor seed in its second stage, and examine it you will find the endosperm is getting exhausted. The two flat thin cotyledons are in close contact with the endosperm tissue and have become fairly large. These cotyledons are able to absorb the materials in the endosperm and pass them on to the radicle and the plumule. That is why the cotyledons are not quite so thin as before. These remain beneath the soil inside the hard testa so long as there are materials to be absorbed from the endosperm. Finally, the hypocotyl arch straightens. The two cotyledons with the plumule are raised up above the soil. Traces of the endosperm can still be seen to be clinging to the lower surface of the cotyledons which now become shining green leafy structures. These are epigeal and they last much longer. The first leaf to appear is not lobed while the succeeding leaves are palmately lobed. Because the cotyledons are large and flat in the seed, they are able to absorb materials from the endosperm without any marked specialisation.

(d) *The Grasses.* In the monocotyledonous seeds several interesting features can be seen in the cotyledon when it becomes specialised during germination. The Grasses, like the Paddy and the Maize, present one peculiarity in regard to the cotyledon. Here the endosperm is bulky and the minute embryo is placed at one end. The cotyledon is the only visible part in the embryo which lies by its back against the endosperm. It is a thin flat leaf rolled into sheath. When germination begins with the absorption of water, the radicle comes out and begins to grow down. The cotyledon shows a special layer of cells on the outer side which is in contact with the endosperm. This layer secretes a ferment with the help of which the material in the endosperm is acted upon and rendered fit for absorption by the cotyledon. The cotyledon is no longer thin but develops into a thick shield in close con-

tact with the endosperm. This specialised shield-like development of the cotyledon is known as *scutellum* and it is very

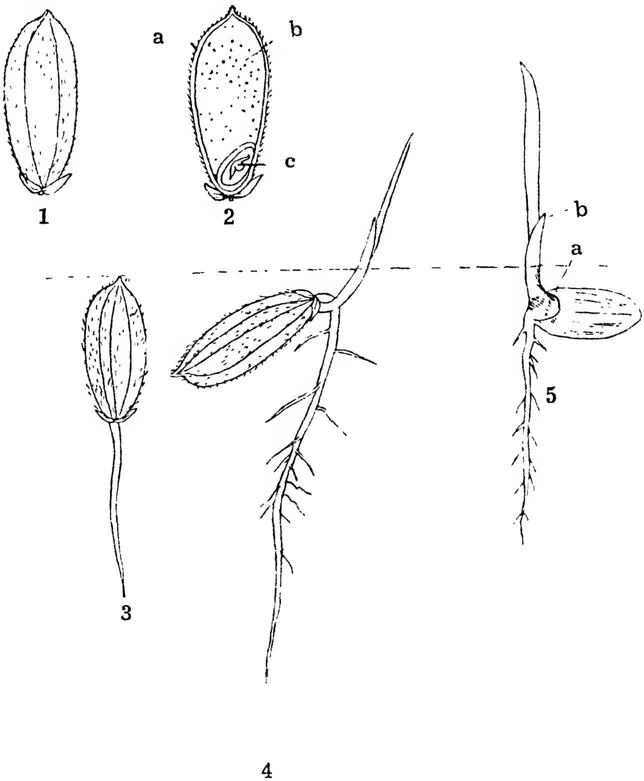


Fig. 137. Germination of the Paddy grain : 1. Grain ; 2. Grain in section : a. Covering, b. Endosperm. c. Embryo ; 3. Germinating grain ; 4. Later stage ; 5. Grain opened out at this stage : a. Scutellum, b. The reduced leaf of the plumule.

useful to absorb the materials from the endosperm and to transfer them to the radicle and the plumule. The plumule is short and pointed and it does not present a broad surface as in the Bean. Hence it is able to bore its way upwards easily through the layers of the soil without being injured. No arching of any kind is needed here since the first leaf of the plumule happens to be short and narrow. The tap-root does not show a tendency to grow well and it ceases to be active at an early stage. Adventitious roots

are produced from the axis very early which grow down to the soil. The cotyledon is hypogeal in the Paddy and the Maize.

(e) *The Palms.* The cotyledon becomes more complex when the seeds of Palms germinate. Observe the different parts of the Coconut in section (Fig. 130). The seed proper is covered by the different layers of the pericarp including the hard stony endocarp. The testa of the seed is indifferently developed and the endosperm known in common language as *copra* is hollow and thick. The embryo is a minute club-shaped body embedded in the endosperm in the region immediately inside one of the three depressions on the stone. The embryo will obviously find it difficult to come out. There is an initial advantage in the position taken up by the embryo. It is situated immediately inside the depression where the stone is comparatively weak. Water is slowly absorbed and the embryo begins to be active. The cotyledon becomes slightly enlarged and exerts a pressure against the endosperm. The weak part of the stone gives way and the broad sheathing part of the embryo protrudes through the pore formed in the stone. This broad part represents the base of the sheathing cotyledon which conceals the rudiments of the rest of the embryo. The pore formed in the stone is called *germ-pore* and the first purpose of the enlarged cotyledon is to push the part containing the radicle and the plumule outside the stone. The tip of the cotyledon remains inside the seed and begins to enlarge. It becomes bigger and protrudes into the cavity of the endosperm. Very soon it becomes a soft spherical spongy structure which comes into contact with the endosperm and absorbs the materials from it. The endosperm shows a corroded appearance owing to the action of the ball-like development of the cotyledon. This portion of the

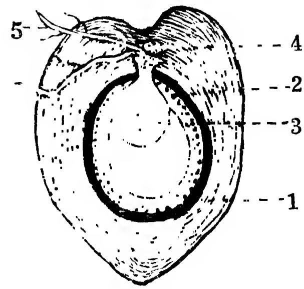


Fig. 138. Coconut germinating : 1. Endosperm ; 2. Pericarp ; 3. Absorbing portion of the cotyledon ; 4. Plumule ; 5. Roots.

cotyledon is useful as an absorbing organ which takes the materials from the endosperm and passes them on to the radicle and the plumule. The basal sheathing part of the cotyledon which has come out serves to protect the radicle and the plumule for a time. When materials are received, the radicle becomes active, splits open the sheath and grows down. But it ceases to grow at an early stage and a few stout adventitious roots are produced from the axis which pass easily through the fibrous mesocarp and reach the soil. The plumule is a short, stiff, narrow structure and it grows up slowly. The leaves of the plumule are tough and they are not spread out. The axis of the shoot is not developing vigorously and hence the leaves are close together. Germination of the Coconut proceeds somewhat slowly and takes a much longer time than that of the seed of the Bean. The Date seed is still more interesting. Here the seed has a tough polished testa with a deep groove on one side. The endosperm is very hard and the minute embryo is situated in the endosperm on the side of the seed opposite to the groove. With the slow absorption of water, germination commences and the cotyledon forming the bulk of the embryo is enlarged. It presses against the testa and a pore is produced. The broad end of the cotyledon comes out enclosing the radicle and the plumule. The tip part of the cotyledon remains inside the seed in contact with the endosperm. As germination progresses, the protruding part becomes longer and grows further down into the soil. The broad part which represents the sheathing portion of the cotyledon protects the tender rudiments inside. The radicle and the plumule are in no hurry to come out of the sheath which grows down

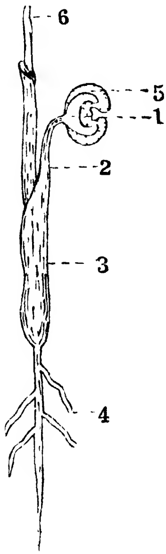


Fig. 139. Germination of the Date seed : 1. Absorbing portion of the cotyledon ; 2. Stalk of the cotyledon ; 3. Sheath of the cotyledon ; 4. Root ; 5. Endosperm ; 6. Shoot.

further and further. When the sheath is examined carefully, it will be found that the part of the cotyledon between the sheath and the tip is differentiated into a long tube-like stalk. What about the tip which is left inside the seed ? It dilates into a broad spongy structure which comes into close contact with the endosperm. The endosperm is by this time very soft and much of the material contained in it has been absorbed by the dilated tip which is thus the *absorbing part* of the cotyledon. The simple cotyledon is differentiated during germination into three parts, an absorbing part, a long tube-like part and a tough sheathing part. When the sheathing part reaches the moist layers of the soil, the radicle and the plumule become active. The radicle comes out and grows downwards into the tap-root which persists for some time. The plumule is a tough structure and the leaf is narrow. It comes out of the sheath and grows up through the layers of the soil. The delay in the activity of the radicle and the plumule is not without advantage. The Date plant grows in dry sandy regions. When the seed happens to germinate in such areas, the root should be brought into contact with the lower moist layers of the soil. Otherwise, the seedling may have to perish for want of water. The elongation of the protruding part takes the sheath lower down until moist layers are reached. But the problem of transport of materials from the endosperm has now to be faced and this is solved by the differentiation of the middle of the cotyledon into a long stalk. **Thus the cotyledon has an absorbing part, a conducting part and a protecting sheathing part.** It is, undoubtedly, a very active structure in this seed. A similar feature is seen in the Palmyra. It will be good for students to observe the germination of different seeds and note the special features in the germination of the Onion and *Crinum*.

Vivipary. A remarkable feature in the germination of the seeds of some Mangroves occurring in marshy or swampy places and backwaters remains to be mentioned. When you look up, you see on the plant a large number of club-shaped bodies protruding from the fruits on the plant. After several days, these are dropped into the substratum as ready-made

heavy seedlings. What has happened is that the seed has begun to germinate even while the fruit is on the tree. The protruding structures referred to above represent the hypocotyl. The germination of the seed is completed even when the fruit is on the tree and the seedling is able to fix itself firmly to the soil by the rapid production of several adventi-

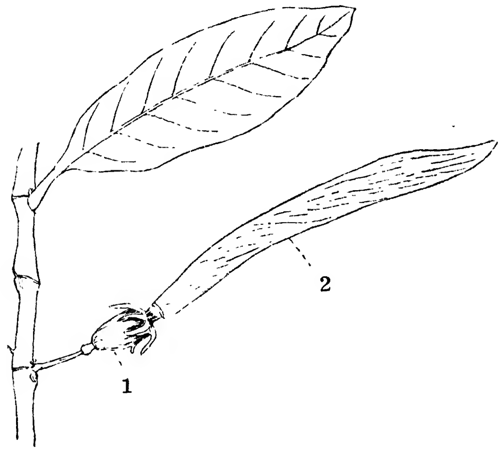


Fig. 140. The Mangroves : Vivipary : 1. Fruit ; 2. Seedling coming out.

tious roots. This premature germination of the seed while on the parent plant is known as *Vivipary* and this condition is advantageous in one respect. The substratum in swampy areas is soft and yielding. The seed will not be left undisturbed for germination to proceed regularly in these areas, especially when the substratum is subjected to the influence of tides. A ready-made seedling has certainly a better chance of getting itself fixed to the soil.

SUMMARY

The seed is the fertilised ovule which has begun to develop in a definite manner.

It consists of seed-coats, a special store-house in several cases, and an embryo.

The embryo is the rudimentary plant which is inactive while in the dry seed.

Seeds are albuminous or exalbuminous according as a special store-house is present outside the embryo or not. There is a provision for food materials in all seeds and the embryo makes use of this stock when it becomes active.

The testa may vary in texture and may also have peculiar outgrowths in the form of hairs or aril.

The reserve materials may be starch or proteins or fat.

Plants are divided into dicotyledons and monocotyledons according to the number of cotyledons in the embryo. The embryo of monocotyledons is minute and club-shaped.

The ripe seed passes through a period of after-ripening and the germination of the seed is possible only under certain favourable conditions. Germination consists of several stages and the cotyledons may be merely passive store-houses or may be specialised to take an active part during germination.

The specialisation noticed in the cotyledon during the germination of the Palms, Paddy and Maize is noteworthy.

Vivipary is a peculiar phenomenon of great interest.

CHAPTER X

DISPERSAL OF SEEDS AND FRUITS

Need for dispersal. What is the significance of the numerous differences that one notices in the form, structure and behaviour of seeds and fruits ? Is there any advantage ? Every seed can give rise to a new individual if the embryo should have a chance. It is in the interest of the race that every individual should be given a chance. Seeds and fruits which are produced in large numbers will be wasted if they should happen to fall close to the parent. There will be great competition for space, food, light and air. It will be a great

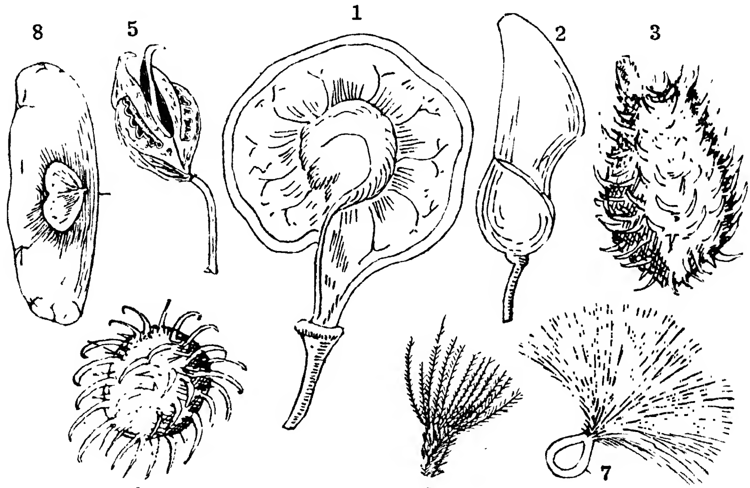


Fig. 141. Dispersal of fruits and seeds : 1 and 2. Winged fruits ; 3, 4, and 5. Spiny fruits ; 6. Achene with pappus ; 7. Comose seed ; 8. Winged seed.

advantage if the seeds or fruits can be carried away from the parent plant. It is immaterial whether the seed or the fruit is transported. What is important is the dispersal of the seed or the fruit. Seeds and fruits are compact structures and the

embryo which is the most important part is well-protected. Plants have thus an advantage over animals so far as dispersal is concerned. Owing to facilities for dispersal, plants are able to reach new areas and to settle there. They have been migrating from time immemorial and those plants are widely distributed which have fruits and seeds adapted for dispersal by some agent or other. It may be expected that plants may easily spread themselves far and wide. But there are several physical barriers like huge mountains, big deserts, and seas, which may act as a check on the distribution of plants. Further, the nature of the soil will also have a share in determining which plant should grow in a locality. In spite of such checks, it is possible for seeds and fruits to be dispersed and the numberless interesting differences in seeds and fruits are, in most cases, seen to be directly connected with the dispersal of seeds and fruits. The dispersal is effected by external agents.

Agents of dispersal. Three agents are employed for the transport of seeds and fruits, namely, *water, wind* and *animals.* Seeds and fruits are ordinarily adapted for transport by one agent or other.

Dispersal by water. Fruits and seeds transported by water are very light and lightness is secured through large air-spaces in them. These seeds or fruits float for a long time in water and there are structural devices to prevent the entry of water into the seed during the period of transport. Premature awakening of the activity of the embryo will amount to wasting the precious seed. *Cerbera odallum* which is common in all tropical coasts is carried a long distance by ocean currents. The large air-spaces in the mesocarp make the fruit light and the pericarp including the stone keeps off water for a long time. The Coconut fruit may be also transported by water. The fibrous mesocarp with large air-spaces makes the fruit light and the entry of water is prevented by the stone. The drupe of *Calophyllum* shows a seed in the big cavity enclosed by the hard stone and the fruit keeps on floating. The seeds of *Ipomaea biloba* can float for a number of days in water and the numerous short hairs keep off the water.

Dispersal by wind. Wind-transported seeds and fruits are light and they float in air for a long time. Strong currents of wind carry them a long distance. A number of plants whose fruits are adapted for dispersal by wind are widely distributed in our plains. These seeds and fruits are usually flat, broad, and light and the presence of wings makes them float in air. *Combretum* is a powerful twiner in the forests and its wide distribution is due to facilities for transport by wind. In the first place, the fruits are produced high up on the crowns of trees over which the branches are spreading. The fruits of Combretum have four fine wings and are very light. Currents of wind carry away a number of these fruits to distant places and they will gradually settle down later on. Wings of seeds serve the same purpose in *Tecoma* and *Millingtonia*. *Calotropis* is a common plant everywhere and it owes its wide distribution to the fact that its seeds are easily transported by wind. When the flat light seed leaves the fruit, the hairs of the coma are close together. Very soon the hairs diverge and the coma acts as a parachute. The seeds remain in air and are carried by currents. Fruits belonging to the Sunflower group possess a similar mechanism and *Tridax* is common everywhere because its achenes have a tuft of hairs called *pappus*.

Dispersal by animals. Animals are also useful as agents for dispersal. There are several plants like the Banyan, the Margosa, the Mistletoe and the Bur which are common everywhere because of the facilities of transport by animals. Among animals, birds form an important group rendering valuable service to plants. Many of the birds have a weakness for fleshy fruits and plants with small fleshy fruits are easily dispersed by birds. The fruits become conspicuous through bright colours and are thus easily recognised by birds. It is essential that the fruits should be disturbed only in the ripe condition and it is interesting to see that the unripe fruit is dull green and not easily distinguishable in the midst of green leaves. Bright colours are assumed only when the fruits become ripe ; and the advantage is obvious. The pulp of the fruit is a substantial inducement to birds which visit plants in search of fleshy fruits. A good number of fruits is swallowed and the birds fly a long distance. They then take rest

on the branches of trees or in the holes in temple towers and a number of seeds is thrown out along with the excreta. These seeds are not at all affected and experiments by means of forced feedings of birds show that several seeds are able to come off uninjured. These are able to germinate and that is why you find Margosa and *Morinda* growing on temple towers or on other trees on the road. The Banyan and Pipal are seen to occur in all odd places. Birds may carry the coloured fruits of these plants and swallow them in a far off place on a tree. It is also likely that the numerous little achenes in these fruits may be clinging to the beak. When the bird is rubbing its beak against the branch of a tree the achenes may be displaced and the Banyan thus has a chance of growing on a Tamarind or Mango plant. It is not fleshy fruits alone that are transported by birds. An unconscious transport of fruits and seeds by birds is possible in regard to aquatic plants. There are numerous seeds and fruits floating in water or embedded in the mud. When birds visit the tank and flap their wings, seeds and fruits may be caught in the feather or a small quantity of the mud containing seeds may also adhere to the feet. When they visit another tank and indulge in a bath, the seeds may be washed out and thus seeds and fruits are carried from tank to tank. Charles Darwin has left on record that, from the mud scrapped from the leg of a bird, he was able to raise as many as 82 plants. Several fruits possess hooks and bristles and such fruits cling to the hairs on the skin of the grazing cattle. Look at *Xanthium* growing near the Paddy field. The dry fruits are easily separated as the grazing animal swishes its tail this way and that way and the numerous hooks on them enable them to readily cling to the tail. *Pupalia* also has similar hooked bristles in the cluster of fruits and the whole cluster clings to the skin. These hooked fruits annoy the animal some time later and they are got rid of. *Tribulus* is a common weed and the spines on the fruit make them penetrate the skin. People pull them out and throw them away in anger. The plant, however, has gained its end. A small plant in the low hills is *Bidens* which shows achenes with bristles and this

plant is widely distributed in the low hills. Wide distribution depends to a great extent upon the facilities for dispersal.

Explosive fruits. There are certain fruits which are not adapted for transport by any external agent but can manage to scatter the seeds through their own efforts. These fruits are called *Sling fruits* or *explosive fruits.* They snap open suddenly with an explosion and the seeds are shot out as if from a sling. In the ripe condition, any slight disturbance may cause the fruit to explode and the seeds will be thrown away. *Justicia* possesses fruits of this type. When the tip of the dry ripe fruit is wetted, it explodes and the seeds are sent out. Balsam has a fruit which, in the ripe condition, opens suddenly on mere touch and the valves roll up quickly with the result that the seeds are scattered.

Plant migration. With such facilities for dispersal, it is natural that many plants should manage to be widely distributed. The migration of plants has been going on and the colonisation of the island of Krakatau after a great volcanic eruption in 1883 bears testimony to the effectiveness of the devices concerned with the transport of seeds and fruits.

SUMMARY

Dispersal of seeds and fruits is a necessity.

Seeds and fruits will be wasted if they should fall close to the parent plant.

The numerous morphological peculiarities of seeds and fruits are in some way useful with regard to their dispersal.

Water, wind, and animals are the three agents that transport seeds and fruits from place to place.

Most of the seeds and fruits are structurally adapted for transport by one or other of the three agents. Plants whose fruits or seeds are adapted for dispersal are certainly widely distributed.

CHAPTER XI

PLANT ANATOMY

General anatomy. Most of the plants possess a body differentiated into the root, the stem, and the leaf. There are some forms among the flowerless plants whose body is very simple. It may be an undifferentiated flat structure or it may

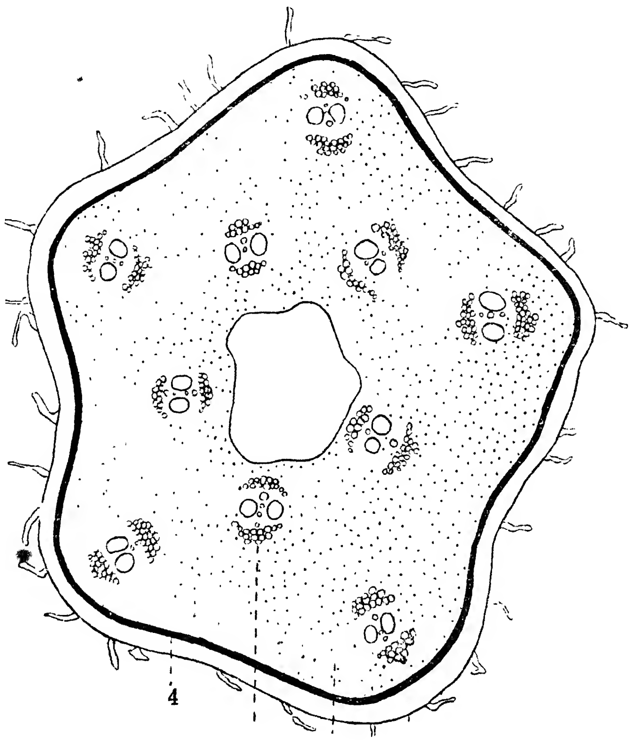


Fig. 142. C. S. of the Pumpkin stem : 1. Epidermis ; 2. Fundamental tissue ; 3. Vascular bundle ; 4. Mechanical tissue.

appear as a minute simple form. Plants which show a body differentiated into organs are usually regarded as higher forms while those with a simple body are described as lower forms.

The organs of the higher forms are easily distinguished from one another by external characters. You would like to know the anatomy and the histology of the different organs. Take a young stem of the Sunflower or Pumpkin and examine its structure. You can easily peel off the skin from the outside. Inside the skin, is seen a soft region. Embedded in this soft part is the well-known hard woody part. These three regions are referred to in common language as the three *general tissues*. Examine the young aerial root of Banyan or a young root of the Sunflower. The same three regions are recognised here and it can be said that the tissues present in the root are the same as those in the stem. The leaf also shows a covering on each of the two surfaces which can be easily peeled off. A green soft tissue traversed by the woody tissue is seen between the coverings. Anatomically, the plant organs are seen to be built up of three kinds of tissues. What is the structure of these tissues ? How does one kind differ from the other ? The internal structure of the tissue can be studied with the aid of a simple lens and more easily with the help of a microscope. Cut thin sections of the stem, the root, and the leaf, and observe the preparations under the microscope. Preparations may also be made from the different parts of the flower and also from any part of the body of the lower plants. When these are examined, you find one important feature in the structure of plant-organs. The plant-body is built up of a large number of microscopic units called *cells*. The cell-structure is found not only in plants but also among animals. The cells may differ in form, size, and structure but all organisms are built up of cells. That the body of all things, whether animals or plants, is composed of cells is a very important idea in biology. Cells are to be regarded as the " bricks " of nature from out of which the tissues are formed. It is necessary that you should know more about the cell.

Parts of the cell. A typical plant-cell shows clearly a *cell-wall* enclosing the important living portion. This living substance is technically called the *protoplast* and it is also usually known as *protoplasm*. The protoplast or protoplasm is, in the words of Prof. Huxley, **" the physical basis of life "**

and all activities of the cell are really associated with it. The protoplast is a complex structure consisting of different parts in intimate relation with one another. It shows (1) a semi-fluid substance, *Cytoplasm,* filling up the cell-cavity, (2) a dark round body, *Nucleus,* in the centre ; and (3) a number of

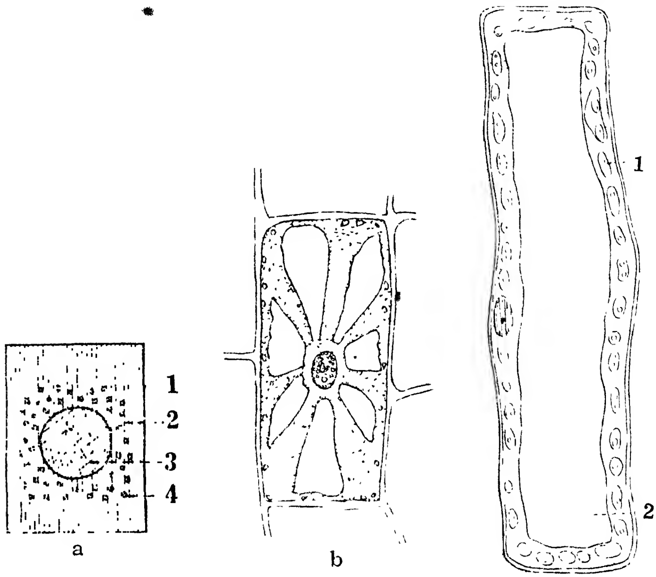


Fig. 143. The Cell : a. Young cell : 1. Cell-wall, 2. Cytoplasm, 3. Nucleus, 4. Plastids ; b. Cell with vacuoles ; c. An old cell ; 1. Chloroplast, 2. Vacuole.

small elliptical bodies, *Plastids,* embedded in the cytoplasm outside the nucleus. The protoplast contains a number of complex chemical substances such as proteins, carbohydrates, and fat. It is the place where chemical changes are constantly going on and substances are being changed. It contains a large quantity of water and is found to be active only in the presence of water. External stimuli such as variations in temperature and intensity of light irritate the protoplast and it is able to adjust itself. It is able to carry on its work only within certain limits of temperature. The protoplast may even show clear indications of movement inside the cells and the fine granules are seen to be carried from place to place inside the cell.

Parts of the cell in detail. (1) The cell-wall is a distinct feature in plant-cells. It forms a protective covering to the protoplasm and is secreted by the protoplasm itself. Chemically, the cell-wall consists of a substance known as *cellulose* and a cellulose wall is thin and admits of being stretched to a certain extent. The cellulose wall allows water and other substances to pass through it and is therefore regarded as a permeable membrane. The cell-wall gives stability to the cell and when the cell grows old, the nature of the wall may be changed. It may become thick owing to the deposition of more materials and its physical nature also may be altered as the result of the deposition of special substances. (2) The semi-fluid cytoplasm fills up the cell-cavity in young cells. As the cell grows and increases in size, small cavities appear in the cytoplasm. The cavities become more distinct as the cell increases in size and these are known as *vacuoles*. The cytoplasm will be seen to be applied to the wall as a thin layer with thread-like projections into the cell-cavity. The vacuoles contain a highly concentrated solution of several substances and this solution is called the *cell-sap*. In course of time, the several vacuoles become reduced to one big cavity and the cytoplasm is seen to form a mere lining against the wall. There are minute granules scattered in the cytoplasm. The outer portion of the cytoplasm which is in contact with the wall is somewhat dense and free from granules while the inner region is rich in granules. (3) The nucleus forms a very important part of the cell. It is easily recognised if the preparation be stained and examined under the microscope. It stands out prominently in the cells when it takes stains. It is always embedded in the cytoplasm.

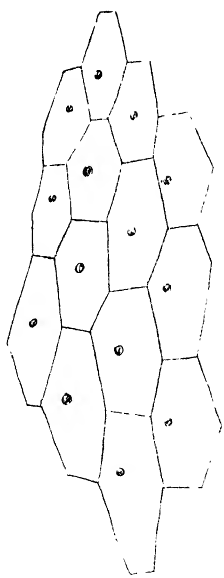


Fig. 144. Epidermis of the scale of Onion with a prominent nucleus in each cell.

The cell cannot be active without the nucleus which takes a leading part in the activity of the cell. The cell is therefore defined as a "**nucleated mass of protoplasm.**" One kind of activity noticed in young cells is their tendency to divide again and again so as to produce new daughter cells. These daughter cells are exactly like the original cell and an increase in the number of cells is possible through this capacity for division on the part of young cells. The nucleus is seen to play a direct part in regard to cell-division and the division of the nucleus precedes cell-division. You will see later on that the nucleus carries the hereditary substance on account of which the Bean and the Mango produce the Bean and the Mango respectively. (4) Lastly, the plastids are special bodies which are small and many in number; and they are technically called *chromatophores.* These are peculiar because they show a tendency to develop different pigments under different conditions. They are therefore to be regarded as pigment producers. In the exposed parts of the plant like the leaves, the plastids develop the green pigment called *chlorophyll.* It is on account of the chlorophyll in the plastids that the leaves are green; and the plastids producing chlorophyll are called *chloroplasts.* In flowers, especially in the petals, the plastids produce yellow or red pigments and these plastids are called *chromoplasts.* The plastids do not develop any pigment when the parts are subterranean.

Tissue. The cell is, as you have already seen, the individual microscopic unit. In the higher organisms, the body should certainly be built up of millions of cells. There are several organisms like *Amoeba* and *Chlamydomonas,* whose body consists of a single cell. The single-celled organism may be minute but yet it is a living thing which behaves exactly like the higher organism. Organisms which consist of a single cell are known as *unicellular organisms* and they are undoubtedly simple and lowly organised. Higher organisms consisting of a body with a large number of cells are *multicellular.* Even higher organisms start life as a single cell, since the fertilised egg which is the starting point of an individual is really a single cell. How does the fertilised egg develop into

a multi-cellular individual? Many cells should have been produced by the fertilised egg and this increase in the number of cells is due to the tendency for division inherent in young cells. Through repeated division a single cell like the fertilised egg produces a cell-group. At first the cells in the group are similar to one another but very soon they show differences in the mode of development. These differences show themselves in form, size, and structure. A few cells, say those towards the outside, may develop along one line while those found in the centre may develop in a different manner. Hence in the cell-mass, there arise several groups, each of which will show special features distinguishing it from the rest. Each of these groups is called a *tissue* and a tissue is thus a group of cells which are similar to one another in form and structure. This differentiation into tissues is a common feature in the organs of higher organisms.

Kinds of tissues. There are three chief kinds of tissues in the organs of higher plants (Fig. 145 and 149) :—

(1) *Epidermal tissue.*

(2) *Fundamental or Ground tissue*; and

(3) *Vascular tissue.*

Each of these three tissues is composed of cells but the cells have developed in a special manner in each case. During the differentiation into tissues, the original cell structure becomes modified. Compare the old part of a stem with the young growing end in the region of the terminal bud. The old part shows clearly the different kinds of tissues in their fully developed state and most of the cells in this region have ceased to divide. They are no longer able to change their structure or to produce new daughter cells. In the growing part near the bud, differentiation has not yet begun. Examine the section of the growing point of the stem. You will see the cells at the growing point have very thin walls and are young and rich in protoplasm. They differ little from one another and they are very active. They are constantly dividing and producing new cells which are later on worked up into some tissue or other. Thus the growing point is different from the older por-

tion of the organ because it consists of more or less similar and actively dividing cells. The purpose of this growing point is to keep up a supply of new cells and the growth of the organ will not be possible but for the formation of new cells at the growing point. This growing point which shows no clear dif-

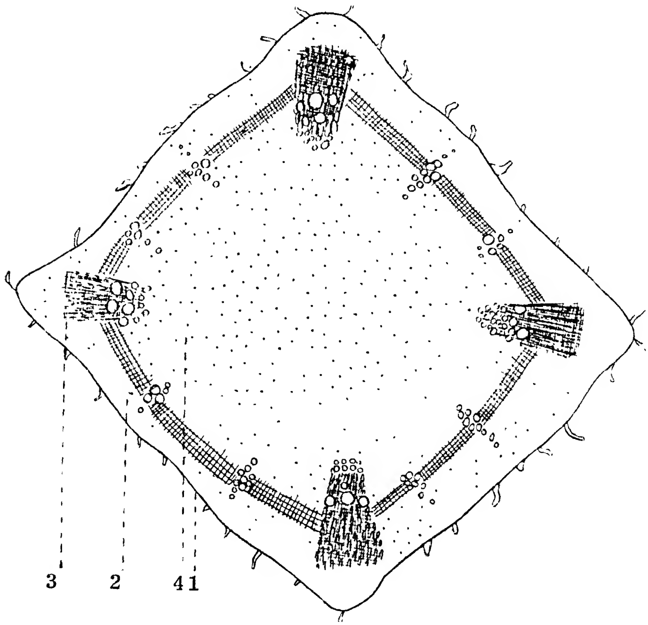


Fig. 145. C. S. of a Dicot stem : 1. Epidermis ; 2. Outer fundamental tissue ; 3. Vascular bundle ; 4. Inner fundamental tissue.

ferentiation into tissues but which constantly goes on producing new cells should be regarded as the *formative region.* Lower down, the cells undergo changes and differentiation into tissues is noticed.

Epidermal tissue. Examine the section of a dicotyledonous stem, say of the Sunflower (Fig. 149-b), or Pumpkin. The epidermal tissue consists of the *epidermis* which is really the skin. It forms a single layer of cells surrounding other tissues. This is a continuous protective layer (Fig. 144) extending throughout the stem. The cells of the epidermis

are generally rectangular in cross-section and they fit one another side by side so closely as to leave no interspace between them. Each epidermal cell is a living cell but the protoplasm is reduced to a lining along the cell-wall and the vacuoles are big. Some epidermal cells are prolonged into hairs which may sometimes consist of a row of cells as in the Pumpkin.

Fundamental or Ground tissue. This forms the bulky part in the organ, especially in the early stages. The massive but soft tissue consists of cells which are spherical or polygonal in cross-section. They have grown equally at all points and possess thin walls. The cells retain the protoplasm and contain a fairly large quantity of water. Cells of the fundamental tissue are known as *parenchymatous* if they are as broad as they are long and if they should have thin walls. The parenchyma cell is kept distended and firm owing to the large quantity of water it contains and the fundamental tissue is thus in a position to contribute to the rigidity of young organs.

The fundamental tissue is not single layered like the epidermis and its cells are arranged close together. Numerous small air-spaces occur freely in this region at the points of contact and these are called *inter-cellular spaces.* The fundamental tissue is continuous throughout the plant body and **the numerous minute air-spaces together constitute the ventilating system of the plant.** The fundamental tissue does not always consist of parenchymatous cells alone. Here and there or in definite regions, cells of the fundamental tissue have developed in a different manner. These are usually longer than broad and look like spindle-shaped fibres with tapering ends. The protoplasm is very much reduced and a substance called *lignin* is also deposited on the wall. The wall becomes thick and strong and the cell-cavity becomes very small. Such elongated cells whose walls are lignified are called *sclerenchyma* cells and these make the fundamental tissue still more rigid. All tissues which increase the strength of the organ are known as mechanical tissues and the sclerenchymatous cells form one kind of mechanical tissue.

The Vascular tissue. This tissue is seen in the form of a number of bundles embedded in the fundamental tissue. These bundles are separately known as *Vascular bundles* which extend throughout the plant body. They form the skeleton or the supporting framework of the body and should therefore be regarded as an important mechanical tissue. The

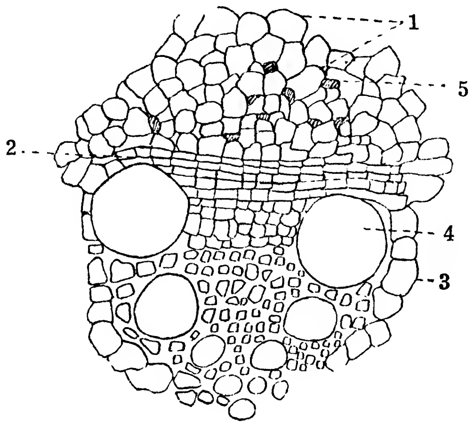


Fig. 146. C. S. of the Vascular bundle of a dicot stem ; 1. Phloem ; 2. Cambium ; 3. Xylem ; 4. Vessel ; 5. Sieve-tube.

vascular bundles which show a complex structure are useful in other ways also. They are the structures through which all kinds of materials are transported. They are therefore also valuable as conducting or transporting organs. A typical vascular bundle is to be seen in the stem of dicotyledonous plants like the Sunflower and the Pumpkin. Observe one of the bundles in the cross-section of the dicotyledonous stem. The bundle consists of (1) an outer group of cells with thin walls, called *Phloem* or *Bast,* (2) a region of young cells called *Cambium* with very thin walls which can be recognised with some difficulty and (3) an inner prominent group with characteristic thick walled elements, the *xylem* or *wood.* Thus the vascular bundle is not a single tissue but is differentiated in its turn into three sub-tissues which are closely associated with one another.

Xylem. The xylem or wood forms the woody tissue and the large cavities surrounded by thick walls which one notices in the section are merely the cut ends of large tubes. These capillary tubes or *vessels* as they are technically called, form the chief part of the xylem and quite a good number of such vessels are found in the xylem of each bundle. In addition to the vessels, the xylem shows parenchymatous elements called

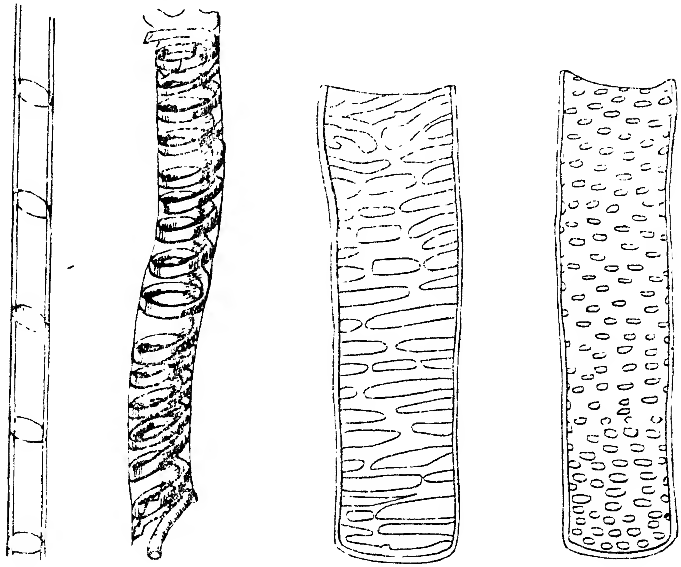


Fig. 147. Kinds of Vessels: 1. Annular; 2. Spiral; 3. Reticulate; 4. Pitted.

wood-parenchyma. The vessel extends lengthwise and it has lost all traces of protoplasm. The vessel is formed from a number of cells. Those cells which are to form the vessel arrange themselves in the early stages end to end in a row. The cross or transverse walls become disorganised and there is thus a continuous tube or vessel produced. Side by side with this change, the protoplasm is used up in the preparation of lignin which is deposited on the wall. Thus the vessel becomes a long dead tube with thick lignified wall. A lignified wall is strong and continues to be permeable. The vessels are therefore very useful as mechanical and transporting elements though they are dead structures. The vessels are not all of

them of the same size. Some are big and some are very narrow. The narrow small vessels are placed more towards the inner part of the xylem while the bigger vessels are on the outer part of the xylem. A longitudinal section of the bundle shows several features peculiar to vessels. The tube-nature is clearly seen and the walls of the vessels differ in appearance. This difference in appearance is due to the difference in the degree of the deposition of lignin on the wall. The narrow vessels show just a few thick rings at intervals on the inside of the vessel and this vessel is called *annular* vessel. Here the lignin is secreted in small quantities and deposited in the form of rings at intervals. The wall portion between the rings is very thin. Close to the annular vessel, may be seen a few vessels with one or two spiral bands traversing the wall. This type of vessel is known as the *spiral vessel* which is somewhat stronger than the annular vessel. The wall portion between the coils of the spiral is thin. Outside these two types of vessels may be seen vessels with a net-work on the wall. This type is called *Reticulate vessel* and the meshes of the net-work represent thin areas in the wall. There is a still another type which shows a number of small pits on the wall. Lignin is so uniformly deposited all along the wall that only small spaces of the wall are left unthickened. These thin spaces appear as *pits*. What is the significance of these different types of vessels ? The vessels are intended to transport water and salts rapidly from the soil to the leaves. They should be strong enough to let columns of water pass through them. But vessels which are thick uniformly are unsuitable for one reason. The water absorbed from the soil by the root-hairs has to enter the vessels in the root first of all. If the walls of the vessels be very thick, water will not enter the vessels quickly. The vessels with thin areas like the annular and spiral vessels will be able to take water readily which then gradually gets into the bigger vessels. In the leaf, water has to leave the vessels in order to be absorbed by the living cells there. Vessels should hence be strong enough to be of use as transporting organs but should, at the same time, have thin areas to let in or to let out water readily as the case may be. A

combination of different types of vessels can secure the necessary strength without interfering with the entrance or exit of water. As for the wood-parenchyma, it is exactly like the ordinary parenchyma cell but the wall is often lignified. It often stores up organic materials like starch and is thus useful as a temporary store-house. Deciduous trees make use of this material in the store-house when they become active and produce shoots in large numbers in the favourable season.

Phloem. The phloem consists of (1) sieve-tubes, and (2) Phloem parenchyma. The sieve-tubes form the important portion of the phloem. The elements of the phloem differ from those of the xylem in one important respect. These retain the protoplasm and possess usually thin walls. Thus they continue to be living cells. The sieve-tube is formed from a number of cells. These cells arrange themselves end to end in a row and they become long and broad. The transverse walls are not at all absorbed but are finely perforated. Hence these cross walls persist at intervals as perforated plates called *Sieve-plates;* and through the perforations in the plate, the contents of one cell in the tube easily flow into the other. Thus a tube is formed for all practical purposes and this is called *Sieve-tube.* The wall is not lignified and the protoplasmic substance passing through the sieve-tube can be made out by examining the longitudinal sections of the Pumpkin stem stained with eosine. The sieve-tubes are intended to transport the organic materials manufactured in the leaf to different places.

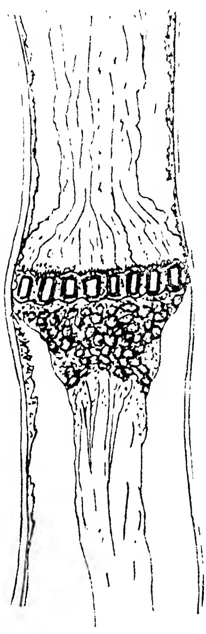


Fig. 148. Sieve-tube.

Cambium. The cambium is a narrow thin region placed between the xylem and the phloem. Its cells have thin walls and prominent nuclei. They are actively dividing

and producing daughter cells towards the inner or the xylem side and also towards the outer or phlœm side. Hence the cambium should be regarded as an active formative layer which adds new elements to the vascular bundles. The elements produced towards the inside become differentiated into wood while those formed towards the outside develop into the phloem elements. Owing to the presence of an active cambium, the vascular bundle of a dicotyledonous stem can receive fresh elements and show an increase in bulk. A bundle where cambium is present is called an *open bundle.* In the stems of monocotyledons, there is no cambium in the vascular bundle which is then described as a *closed bundle.*

SUMMARY

Living things are built up of cells which form microscopic units. The cells are nature's bricks.

The living protoplasmic substance is highly complex and it forms the physical basis of life.

The young cell is capable of producing by division new daughter cells. Organisms may be uni-cellular or multi-cellular.

Even multi-cellular organisms start life as a single cell. When a cell-group is produced by division of the cell, the cells develop in different ways and thus different tissues are produced.

There are three chief tissues in the plant-body, the Epidermal, the Fundamental and the Vascular.

The epidermal tissue forms the skin which protects the other tissues. The fundamental tissue forms the bulk of the organ, especially when young, and shows numerous inter-cellular spaces. The vascular tissue consists of a number of vascular bundles which possess specialised vessels and sieve-tubes for the transport of materials. The vascular tissue is also important as a mechanical tissue.

CHAPTER XII

ARRANGEMENT OF THE TISSUES

Tissue system. The three major tissues in the plant body namely the *epidermal*, the *fundamental* and the *vascular*, form the three tissue systems. Each system forms a continuous system throughout the plant body. The arrangement of the tissues in the different plant organs is such as to enable them to perform their functions efficiently.

Arrangement of the tissues in the stem. Cut transverse sections of the stems of the Sunflower and Maize and examine them under the lens. You can see the general arrangement of

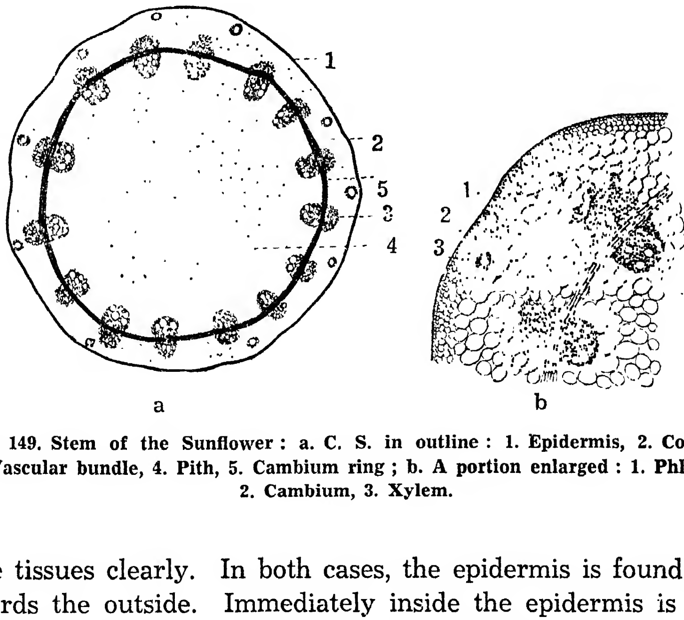


Fig. 149. Stem of the Sunflower : a. C. S. in outline : 1. Epidermis, 2. Cortex, 3. Vascular bundle, 4. Pith, 5. Cambium ring ; b. A portion enlarged : 1. Phloem, 2. Cambium, 3. Xylem.

the tissues clearly. In both cases, the epidermis is found towards the outside. Immediately inside the epidermis is the fundamental tissue. Embedded in the fundamental tissue are seen a few vascular bundles arranged in a broken ring in the Sunflower. Owing to the occurrence of the broken ring of vascular bundles in this plant, the fundamental tissue is itself divided into two regions, the region outside the vascular bundles known as *cortex* and the region enclosed by the

vascular bundles known as the *pith.* The bundles are at first separated laterally from one another by fundamental tissue extending from the pith to the cortex. In the case of the Maize, the vascular bundles are more numerous and are also of different sizes. These bundles are not arranged in a ring but they appear to be scattered in the fundamental tissue.

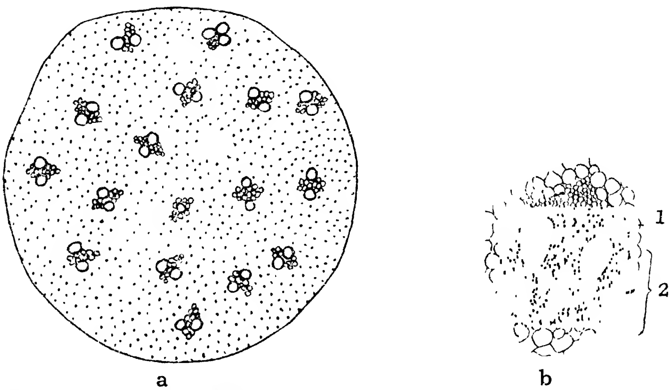


Fig. 150. Stem of the Maize : a. C. S. in outline showing the three tissues. b. A single vascular bundle : 1. Phloem, 2. Xylem.

Consequently the fundamental tissue is not divided into cortex and pith. The arrangement of the bundles in a broken ring is characteristic of dicotyledonous stems while the bundles are scattered in the monocotyledonous stems. More details can be understood by observing the sections under the microscope. The epidermis is seen to be a single layer of rectangular cells. The outer wall of each epidermal cell is rather thick. The fundamental tissue is chiefly parenchymatous and shows numerous fine inter-cellular spaces. Groups of sclerenchyma cells are noticed close to the vascular bundles in the Sunflower or close to the epidermis in the Maize. The parts of the vascular bundle are clearly distinguished. The bundle of the dicotyledonous stem represented by the Sunflower is of the open type consisting of the phloem, the cambium and the xylem while in the Maize representing the monocotyledonous stem, the cambium is wanting and the bundle is of the closed type. This absence of cambium makes a great difference later on. In all stems, whether mono-

cotyledonous or dicotyledonous, the phloem is near the cortex and forms the outer portion of the bundle ; the xylem is near the pith and forms the inner part of the bundle. The cambium is in between the two when it is present. The xylem shows a definiteness in the arrangement of the vessels. The narrow vessels like the annular and the spiral vessels which are the first to appear and which form the *proto-xylem* always adjoin the pith. The reticulate and pitted vessels formed later on are found away from the pith. Since the phloem occurs close to and behind the xylem on the same radius, the bundle of the stem is described as *collateral.*

Structural changes in old stems. As the stem grows old it shows certain characteristic changes which are clearly seen in the dicotyledonous stems. An old stem of a dicotyledonous plant shows appreciable increase in thickness and it continues to increase in thickness. It also becomes brown and shows the presence of *bark.* The stem of a monocotyledon does not show ordinarily any increase in thickness. Just imagine the difference between the big trunk of the Tamarind and the slender stem of the Maize. This difference is to be attributed to the presence of the cambium in the vascular bundle of the dicotyledonous stem. If a slightly old dicotyledonous stem be cut across and examined, the bundles are no longer seen to be independent of one another. They become united together and thus a ring of wood is formed. A section will show easily inside the cortex, rings of phloem, cambium and xylem one inside the other and the pith is almost crushed. The wood is rather more bulky. This is brought about in the following manner. At first the bundles are in a broken ring separated from one another laterally by rays of fundamental tissue. Very soon, the activity of the normal cambium spreads to the parenchyma cells in the fundamental tissue situated close to the cambium. Thus, alternating with the normal cambium may be seen parenchyma cells becoming active and assuming the form of cambium. These new cambium strips which originate in the ordinary fundamental tissue form *secondary formative tissue,* but they behave exactly like the cambium. Very soon these strips become

connected with the adjoining normal cambium strips so that a cambium ring is formed (Fig. 149). Once the cambium ring is formed, cells are produced in a ring towards the xylem and they show the nature of the xylem while those produced towards the phloem become the phloem. Hereafter the wood, the cambium, and the phloem will be seen only as continuous rings. More elements are added to the xylem and hence the wood is more massive. The trunk of the Tamarind is the result of the activity of the cambium ring produced as described above and shows massive wood. The dicotyledonous stem can go on increasing in thickness and it can therefore carry a larger number of branches and leaves. The formation of bark is also a common feature in dicotyledonous stems. How is it that the outer portion of the stem becomes a brown bark ? The bark is thin and scaly as in Guava or thick as in Mango. The bottle cork represents the bark of an Oak. Some of the cells in the cortical region show a tendency to become active. After a few preliminary divisions, these cells acquire the characteristic features of cambium cells. It is extraordinary that ordinary parenchyma cells which have become permanent tissue should, under special conditions, be able to become active. The activity of these special cells extends to the adjacent cells by their side. Gradually the active zone is spreading in the cortex and finally it becomes a continuous ring. It looks like a cambium and its cells are dividing. It is really a secondary formative layer and since the product of this layer is a special tissue known as cork, this layer is known as *cork-cambium* or *Phellogen.* This new formative layer which is developed in the cortex produces a few parenchyma cells towards the inside and a large number of special cells towards the outside. The cells towards the outside are rectangular cork-cells which are arranged in regular rows like bricks without leaving inter-spaces. A noteworthy feature of these cells is the deposition of a special substance known as *suberin* or *cork* on the walls. The cells lose their protoplasm and become dead cells and their suberised or corky walls make them impervious to water and gases. The development of an impervious cork

tissue in the middle of the original fundamental tissue should result in cutting off water supply to the cells in the region situated outside the cork zone. The cork tissue becomes dry and all the remnants of the fundamental and epidermal tissues

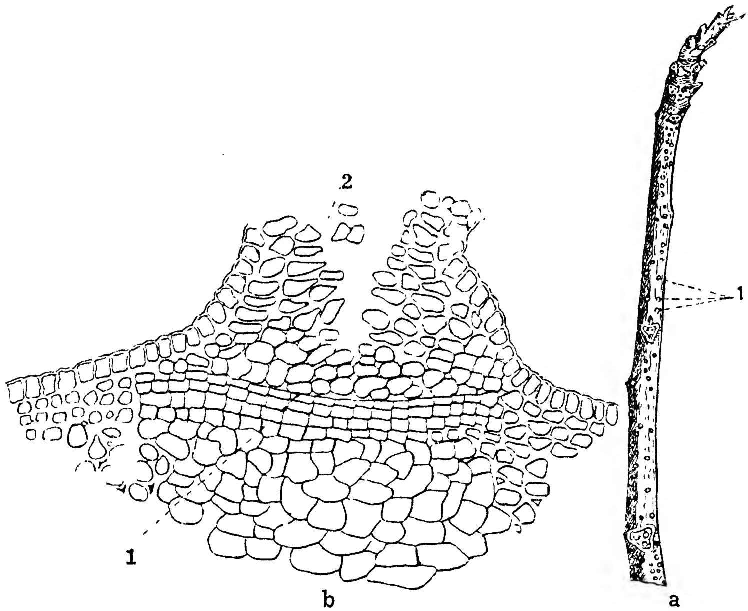


Fig. 151. Lenticel in the Bark : a. A twig : 1. Lenticels ; b. C. S. of the stem at the region of the lenticel : 1. Cork-cambium, 2. Lenticel.

found outside the cork must become dry and die. All these dried tissues consisting of the cork and the old tissues outside it turn dry and brown and together constitute *bark*. The bark will be thick if the cork-cambium should originate in the innermost region of the cortex. A good part of the cortex will then be outside the cork tissue and thus the bark will be massive. If the cork-cambium should arise in the outer part of the cortex, say close to the epidermis, the bark is bound to be thin. Bark is useful to the plant in several ways. On account of the impervious nature of the cork, the bark is able to prevent the loss of water from the trunk, a danger which has to be avoided in plants growing in dry regions. How is it that the common potato tuber is able to retain its water ? Peel

off the covering which is a thin corky tissue and observe the difference. It is also useful as a protective cover and keeps off the spores of disease-producing fungi. When the leaf falls or when a branch is cut, the wound is healed by the formation of cork. A remarkable feature in the activity of the cork-cambium is the formation of fine lens-shaped slits or passages known as *lenticels* in the epidermis. At certain points, the cork-cambium produces towards the outside a cluster of loose parenchyma cells instead of cork cells. This group of cells ruptures the epidermis and a fine slit or *lenticel* is formed. The loose cluster of cells is permeable and allows exchange of gases to take place through the lenticel slowly.

Arrangement of the tissues in the root. Examine the cross-section of a young root. You see the thin epidermis to-

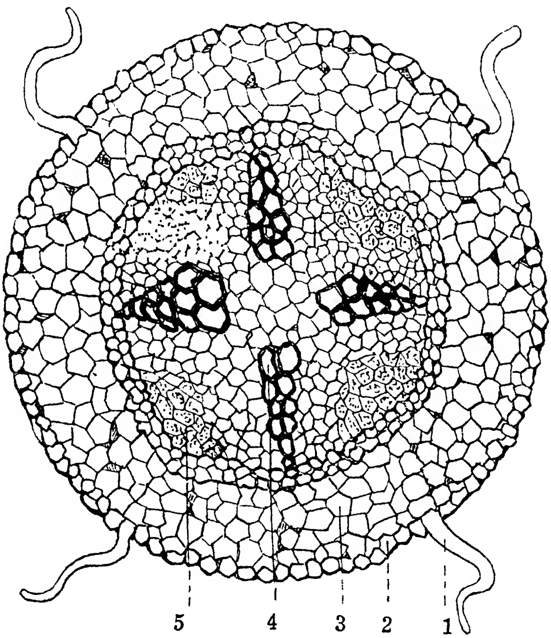


Fig. 152. C. S. of a dicot Root : 1. Root-hair ; 2. Epidermis ; 3. Cortex ; 4. Xylem ; 5. Phloem.

wards the outside. The cells of the epidermis have thin walls and many of the cells are prolonged into fine processes. These

prolonged cells are the root-hairs which show the thin, permeable, cellulose wall, the cytoplasm, and the vacuoles very clearly. On account of the special tendency for producing root-hairs, the epidermal layer in young roots is also known as *piliferous* layer. The fitness of this layer for the absorption of water is obvious. Inside the epidermis, is seen a prominent cortex containing parenchyma cells and the innermost layer of the cortex appears as a clear ring of cells called *Endodermis*. The pith which may not ordinarily be well developed is seen in the centre. The vascular bundles of the root are peculiar in one or two respects. There is no cambium in the first place. Secondly, the xylem and the phloem occur not on the same radius one behind the other but in independent groups on different radii and regularly alternating with each other. There are a few xylem and phloem groups in the dicotyledonous roots while in the monocotyledonous root, the number may be several. In the monocotyledonous root the pith is fairly big and the xylem groups are smaller though more numerous. The xylem consists of different kinds of vessels and the arrangement of the vessels is quite the reverse of that in the stem. The protoxylem consisting of the annular and spiral vessels, is placed close to the cortex while the bigger vessels are near the pith. What do you think to be the advantage from the point of view of the work of the vessels ? The epidermis absorbs water with the help of the root-hairs. The cortex passes on the water received from the root-hair to the vessels. The protoxylem is able to take this water readily at first on account of the large thin spaces on the wall. The root shows changes in the older region. For instance, the epidermis is lost and in the absence of root-hairs the older portion is not able to absorb water.

Arrangement of tissues in the leaf. The blade is the most important part of the leaf. The petiole repeats more or less the structure of the axis. The blade is flat and spread out horizontally. Examine the cross-section of a blade. You will see an epidermis on the upper side and this is called *upper epidermis*. Its cells are rectangular and closely fit one another so as to leave no interspace. The outer wall of each

epidermal cell in the leaf shows some peculiar features. The outer wall is thick and a waxy substance called *cutin*

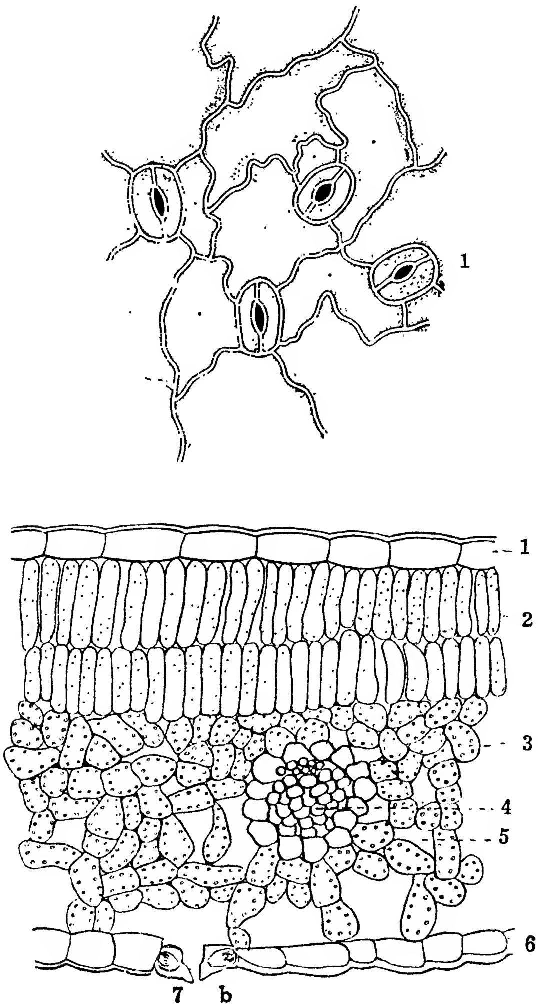


Fig. 153. Structure of the Leaf : a. Lower epidermis on surface view : 1. Stoma with two guard-cells, b. 1. Upper epidermis, 2. Palisade tissue, 3. Spongy tissue, 4. Vascular bundle, 5. Inter-cellular Air-spaces, 6. Lower epidermis, 7. Stoma in section.

secreted by the protoplasm appears on the surface of the outer wall as a thin film. Since the epidermal cells are placed

close together side by side in a line, the deposit of cutin on the outer walls of all the cells may become marked and a tough layer, called *cuticle,* arises on the outer surface of the leaf. The development of the cuticle is a special feature of the epidermis of leaves and the cuticularised (containing cutin) epidermis is always an impervious layer. The leaves are likely to lose much water readily since they expose their broad, flat, and thin surface to the sun; and the cuticularised epidermis serves to minimise this loss of water. It is thus a protective layer which is specially valuable to plants growing in dry regions. On the lower surface also is seen an epidermis called *lower epidermis.* This differs from the upper in showing numerous microscopic holes called *stomata* (stoma—singular). In the leaves of plants growing on land, the stomata are developed in large numbers in the lower epidermis and few will be seen on the upper epidermis. If the lower epidermis be peeled off and examined under the microscope, the stomata are seen clearly in surface view. Each stoma is bounded by a pair of bean-shaped living cells called *guard-cells.* Millions of stomata are present in the lower surface of the leaf. The hole with the two guard-cells is also collectively termed *stoma,* and the size of the aperture can be increased or reduced by a change in the form of the guard-cell. The tissues of the leaf and the entire ventilating system of the plant communicate with the atmosphere through the stomata. The stomata constitute therefore a delicate but effective mechanism for regulating the exchange of gases. The rate of exchange will depend upon the size of the aperture and the number of the stomata. The guard-cells are living cells rich in protoplasm; and unlike the other epidermal cells, they contain chloroplasts The form of the guard-cell varies according to the quantity of water present in it and the size of the aperture varies with the change in the form of guard-cells. When more water enters the guard-cells the guard-cells become distinctly bean-shaped and the aperture is kept wide open. This change of form in a definite way is helped by the unequal thickening of the wall of the guard-cell adjoining the pore. When water is withdrawn from the guard-cells, the walls of the guard-cells adjoining the pore

are close together and the guard-cells are not distinctly bean-shaped. The aperture is practically closed. A cross-section of the leaf shows the lower epidermis to be like the upper epidermis in other respects. The stoma is really derived from an epidermal cell which, by growing and dividing in a special manner, gives rise to the aperture and the guard-cells. In the cross-section a fairly big air cavity is seen close to each stoma inside the leaf. In between the two epidermises is situated the fundamental tissue of the leaf and the vascular bundles traverse the lower region of the fundamental tissue in all directions. The fundamental tissue of the leaf has got some special features and is called by a distinct name, *Mesophyll.* The mesophyll is divided into two portions, an upper portion and a lower portion. The upper portion is dark green and consists of one or two layers of long and narrow cells closely packed together and arranged at right angles to the epidermis. This region of long and narrow cells is called the *palisade tissue* and the cells of this tissue show a large number of chloroplasts in the cytoplasm. Owing to the large number of chloroplasts present in the upper or palisade tissue, the upper surface of the blade is green. Air spaces are not easily recognised between the cells of the palisade tissue. The lower portion of the mesophyll is called *Spongy tissue.* It consists of cells with irregular outline and there are numerous inter-cellular spaces in this region. Hence the tissue appears as a loose one. There are chloroplasts in the cells of the spongy tissue but they are fewer. That is why the lower surface is not dark green. The palisade tissue is in contact with the spongy tissue. The vascular bundles traverse the lower part of the blade, namely, the spongy tissue region. Since the bundles are spreading in all directions in the blade, many of the smaller veins will appear to have been cut obliquely in the section. The bundles of the leaf have no cambium; and the xylem points to the upper surface while the phloem points to the lower surface. The smaller bundles will naturally have fewer elements and the xylem in these fine veins becomes reduced to a few spiral vessels. These are in direct contact with the living green cells of the leaf and the exchange of materials becomes easy. The epidermal layers serve to pro-

tect the mesophyll and to prevent the loss of water. The mesophyll is directly connected with the manufacture of complex organic materials. The palisade tissue takes a prominent part in regard to the preparation of materials while the spongy tissue plays a subordinate part and helps considerably in facilitating the exchange of gases through the inter-cellular spaces. The vascular bundles support the tender blade and also serve to transport materials to and fro.

A Great architect. Plant-engineering is by no means simple. Plants are rooted to the soil and have to get on there in fair weather and foul. Many are the details to be carefully attended to. The structure of the cell, the differentiation into tissues, and the organisation of the plant-body are all calculated to enable plants to make the best use of their opportunities. Nature is undoubtedly a great architect. How far is this delicate machinery fitted to perform the day-to-day functions ?

SUMMARY

The Epidermal tissue, the Fundamental tissue, and the Vascular tissue form the three tissue systems of the plant body. Each system forms a continuous system throughout the plant body.

The arrangement of the tissues in each organ is such as to enable it to perform its functions properly. The stem of a dicotyledon differs from that of the monocotyledon in important respects.

The activity of the Cork-cambium in the fundamental tissue leads to the formation of cork which prevents the undue loss of water.

Lenticels are useful to facilitate the exchange of gases.

The structure of the root is peculiar in that xylem and phloem groups occur on separate radii. The occurrence of the protoxylem towards the outside close to the cortex enables water to get into the xylem readily.

The structure of the leaf is altogether different. The fundamental tissue is specialised for the purpose of assimila-

tion. The cuticularisation of the epidermis helps to minimise the loss of water. The stomata are the pores through which the entire ventilating system of the plant-body communicates with the outside. They form a fairly good apparatus for

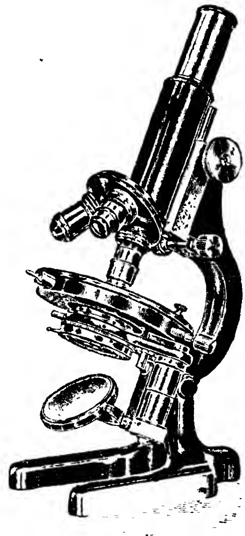


Fig. 153-A. The Microscope.

regulating the loss of water from the leaf. The inter-cellular spaces of the leaf in the spongy tissue are very useful for facilitating the exchange of gases. The presence of chloroplasts in the cells of the mesophyll makes the leaf green. The vascular bundles traverse the spongy tissue.

CHAPTER XIII

PLANT PHYSIOLOGY : NUTRITION

Functions of plants. Plant physiology deals with the several activities of living plants. Plants take food, respire, grow, move, and also reproduce their own kind. These different activities are known as *Nutrition, Respiration, Growth, Movement,* and *Reproduction* respectively.

Food. What is the food of plants ? Wherefrom is it obtained ? How is it absorbed ? What happens to it in the plant-body ? These are questions which you will ask in connection with food. All activities relating to the food of plants constitute *Nutrition.* No plant can get on without a supply of materials from outside. These materials cannot be directly utilised as food by the living plant. They are certainly in the nature of crude or raw materials and they are spoken of as food only in a general sense. They should be strictly regarded as *raw food* which has to be acted upon in different ways inside the plant before it can be converted into the food proper or *plant-food.* You have learnt already that the plant-organs are built up of cells, each of which has got a well-defined cell-wall. It is essential that the raw food should be presented in a liquid form if it should enter the body. The simple raw food is worked up inside the plant-body into carbohydrates and proteins. These substances are complex organic substances which go to make up the protoplasm ; and they therefore form the real plant-food.

Raw food. The plant obtains, as raw food from outside, (1) *water,* (2) *mineral salts* such as *nitrates, phosphates,* and *sulphates,* and (3) *carbon-dioxide.* Water and mineral salts are obtained from the soil while carbon-dioxide is absorbed from the atmosphere. These raw materials are mostly inorganic compounds but they contain among them the ingredients present in the protoplasm. From out of these inorganic substances received from outside, the living plant prepares complex organic foodstuffs, such as carbohydrates

and proteins. Carbohydrates are non-nitrogenous substances consisting of carbon, hydrogen and oxygen. Proteins are complex nitrogenous substances which contain nitrogen in addition and also in some cases, sulphur and phosphorus. The raw food should contain carbon, hydrogen, nitrogen, oxygen, sulphur and phosphorus in some suitable combinations since these enter into the composition of the carbohydrates and proteins. Other substances are also found necessary. Much of the weight of a plant is due to the large quantity of water present in it. The dry substance left after the withdrawal of this water is combustible and is rich in carbon as shown by the charring of the plant. A small quantity of incombustible residue or ash is always left on burning plants and a chemical analysis of the ash shows the presence of several elements such as potassium, calcium, magnesium, sodium and iron. These substances in the ash may be useful to the plant in some way or other though they may not enter into the composition of food. The raw food contains several kinds of materials, some of which may have no purpose to serve in the plant. They may be there by mere chance. Which substances are essential for the life of plants ?

Essential elements. Attempts have been made to grow plants in several glass jars containing distilled water to which a few mineral salts are added in small quantities. The composition of the nutritive solution is not the same in all the jars and the growth of plants under different nutritive conditions is studied. Such a procedure is called *water-culture experiment*. The solution which allows a plant to grow well further and further should be regarded as a suitable one containing all the necessary substances. Some mineral salt or other is withheld in the case of certain jars and the behaviour of plants is noted. For instance, when no compound of potassium is supplied to the solution, the plant is not healthy and appears dwarfed. If no trace of iron compound be added, the leaves become white or *chlorotic*. If no nitrate is supplied, there is no growth. It is obvious that certain substances are essential. The following is known as Knop's Solution and it has been found adequate for the normal growth of plants :

Water	..	1,000 c.c.
$Ca(NO_3)_2$	..	1·0 gm.
KNO_3	..	0·25 „
KH_2PO_4	..	0·25 „
$MgSO_4$	..	0·25 „
$FeCl_3$	..	Traces

Other solutions of a slightly different composition have also been tried with success by other investigators. It is noteworthy that the ideal nutritive solutions contain no carbon compound at all and yet the plant shows considerable increase in carbon. This proves that the carbon which forms the important constituent of plants is obtained from the carbon-dioxide of the atmosphere. Equally interesting is the fact that plants cannot make use of the free nitrogen of the atmosphere. They derive the nitrogen from the nitrates supplied to them. The results of water-culture experiments show that the raw food should be in the form of inorganic compounds and that they should, among themselves, show, in some combination or other, the following ten elements: Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Phosphorus, Potassium, Calcium, Magnesium and Iron (Twelve according to recent investigators: Boron and Manganese). It should be understood that no food can be taken as an element; and the raw food should contain in some form all the elements which are essential for the life of plants. If any one be wanting, the growth of plants will be seriously affected. In nutrition there are two aspects to be considered. Firstly, there is the problem of *absorption* of the raw food by the plant from outside. Secondly, you should consider how this raw food is acted upon in order to become incorporated in the protoplasm. The second aspect which involves complex chemical changes inside the plant-body is termed *assimilation*. Carbon-dioxide, water, and mineral salts such as nitrates, sulphates and phosphates constitute the raw food and contain all the essential elements.

Absorption of CO_2. The atmospheric carbon-dioxide is the only source of carbon. It exists in very small proportion but the supply is fairly adequate. The leaves which are

spread out in air are well-fitted to absorb carbon-dioxide. You know that the lower epidermis of the leaf shows numerous microscopic holes or stomata. The stomata remain open in sunlight and the atmospheric carbon-dioxide passes through the stomata into the leaf. It diffuses into the air-cavity close to the stoma and from there it diffuses into the numerous inter-cellular spaces in the spongy parenchyma of the leaf. Adjoining the air-spaces in the leaf are the green cells. The cell-walls of these cells are never dry. Carbon-dioxide becomes dissolved in the water of the wet cell-wall and then readily diffuses into the cells of the spongy parenchyma. Gradually it diffuses from this tissue into the cells of the palisade tissue. The mesophyll of the leaf, especially the palisade tissue, becomes rich in carbon-dioxide. It is here that the carbon-dioxide is going to be worked up.

The soil and its nature. Plants obtain water and salts from the soil. The soil consists of sand particles of varying sizes loosely held together so as to leave interspaces. Along with these particles may be mixed up fragments of decaying leaves and stems forming the *humus*. The characteristics of the soil vary a great deal. Thus, there are sandy, clayey, gravelly and loamy soils. There are several kinds of mineral salts present in the soil. When it rains, the soil becomes moist. The rain water may be drained away. But a

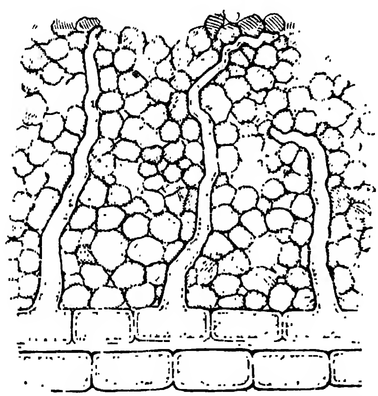


Fig. 154. Root-hairs in contact with the soil.

portion of this water percolates into the soil and displaces the air in the spaces. Certain soils like the sandy and gravelly ones which posses fairly big particles allow water to soak rapidly while the clayey soil containing fine particles does not allow the water to go down. The rain water distributes itself widely in the soil in course of time and surrounds the

particles of the soil as thin films so that the spaces in the soil are again occupied by air. The film of water contains traces of a number of mineral salts in solution such as nitrates, phosphates and sulphates. Plants depend upon this film of water which is therefore termed *nutrient water.* The root grows in the soil and the root-hairs which are seen to be directly associated with the particles of the soil absorb this nutrient water in the soil.

Absorption of the nutrient water. How does the nutrient water enter the root-hair ? The root-hair is a prolonged epidermal cell with a distinct cell-wall. The nutrient water of the soil will have to pass through the cell-wall and the protoplasmic substance before it can get into the root-hair. That the nutrient water can pass through the cell-wall and the layer of protoplasm is clear from the following experiment.

Experiment 1. Take a beaker and a thistle funnel. Get a piece of membrane, stretch it over the wide mouth of the funnel and tie it air-tight. Pour water into the beaker. Fill up the wide part of the thistle funnel with the solution of copper sulphate. Arrange to hold it in such a way that the wide mouth dips into the water in the beaker. Note the level at which the solution stands in the tube. In about half an hour, the solution begins to rise in the tube and it goes on rising in the tube for a time. Evidently, the water contained in the beaker has readily passed into the thistle funnel through the membrane. On the other hand, the copper sulphate has not yet got into the beaker. Keep the apparatus standing for a time and the copper sulphate may slowly diffuse into the beaker. The membrane is said to be permeable. The passage or diffusion of a liquid through a permeable membrane

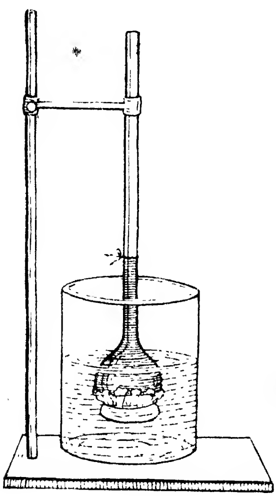


Fig. 155. Osmosis.

separating two liquids differing in concentration is a purely physical process known as *Osmosis*.

The nature of the membrane may make a great difference in regard to osmosis. A membrane need not be permeable to all substances. It may allow only certain substances to pass through and prevent other substances from diffusing. It is then regarded as a *semi-permeable membrane* or strictly speaking as a *differentially permeable membrane*. In nature the position is more or less the same as in the experiment but there is the differentially permeable membrane in the form of the protoplasmic living substance. The nutrient water outside the root-hair is a dilute solution while the cell-sap inside the root-hair is a highly concentrated solution owing to the presence of complex substances in it. These two solutions are separated from each other by (1) the cell-wall and (2) the protoplasmic layer lying close to the wall. The penetration of the cell-wall by the nutrient water is rather simple since the cellulose wall is readily permeable to all the substances in the nutrient water. It has still to pass through the protoplasmic layer which behaves like a differentially permeable membrane. This layer allows only certain substances in the nutrient water to diffuse into the cell while it does not ordinarily permit the materials in the cell-sap to leave the cell. It thus seems to possess a selective or discriminating power. More substances can get in while few materials can leave the cells under ordinary conditions. When a differentially permeable membrane separates two solutions containing several substances in varying proportions, **the diffusion of each of these substances through the membrane takes place separately** according to certain well-defined laws relating to partial pressure differences, provided that the membrane is permeable to it. Thus the different substances in the nutrient water happen to diffuse into the root hair in different proportions and some may not enter at all. The absorption of the nutrient water by the root-hair is **an osmotic process**. On account of the differentially permeable nature of the living protoplasmic substance, a selection of materials contained in the nutrient water always takes place. Consequently, the

nutrient water which has got into the root-hair does not contain all the substances found originally in it while in the soil. When the root-hair absorbs water, it increases slightly in volume. Further absorption of water exerts a pressure on the cell-wall and the root-hair becomes very rigid like an inflated bladder and it is then said to be *turgid.*

Root-pressure. What happens to the water absorbed by the root-hairs ? These lie close to the cortex whose cells have thin walls and contain a cell-sap of higher concentration. Water is osmotically passed on from the root-hairs to the outer cells of the cortex. These outer cortical cells become turgid

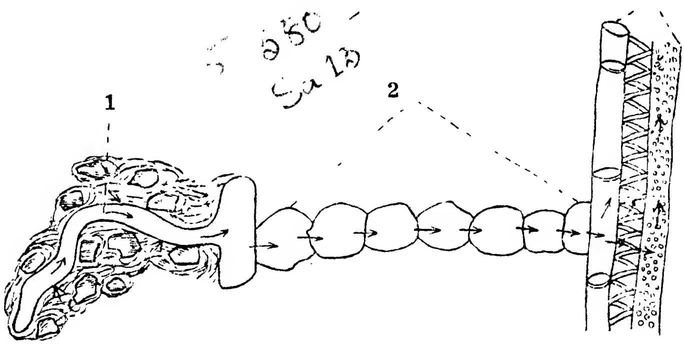


Fig. 156. Entrance of water : 1. Root-hair with particles of the soil ; 2. Cortical cells ; 3. Vessels. (Diagrammatic).

in their turn and the cell-sap in them is not now so highly concentrated on account of the absorption of more water. Since the cortical cells situated further inside have a more highly concentrated cell-sap, water diffuses osmotically into the inner region of the cortex. Thus in a short time the entire cortex receives plenty of water and becomes very turgid. A great pressure happens to be developed in the cortex of the root and this pressure is usually called *root-pressure.* The walls of the cortical cells cannot be stretched indefinitely and the water that has been passed osmotically from cell to cell in one direction towards the centre is finally forced into the vessels of the xylem adjoining the cortex. What is the

advantage in having spiral and annular vessels close to the cortex? That the water is forced into the vessels of the root is evident from the fact that it rises upwards in the vessels. The following experiment demonstrates root-pressure.

Experiment 2. Take a pot-plant of Balsam or *Coleus,* and cut off the stem so as to leave only a short stump in the pot. Slip over the cut end of the stump a short rubber tube so as to connect it with a glass-tube. Fill up the rubber tube with water and thrust a long glass-tube into the free end of the rubber tube. The two ends of the rubber tube should be tied air-tight. Mark the level at which water stands in the glass tube to begin with. Keep the apparatus for a while in the shade and observe. Water rises in the glass tube in about fifteen minutes. If you continue to observe, you will find that more water enters the glass tube and rises up the tube. It may even overflow if the apparatus be not disturbed. Notice that the overflowing water leaves, on evaporation, traces of salts on the tube. It is clear that the root of the pot-plant has absorbed water along with the salts and that this water is passed on to the stem. The rise of water in the glass tube further shows that pressure should have developed in the root.

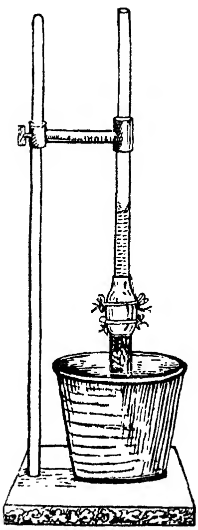


Fig. 157 Root-pressure.

Path of the nutrient water. The nutrient water of the soil enters the root-hairs in the first place. It is then passed on to the cortex of the root and owing to the development of root-pressure in this region is forced into the vessels in the wood of the root. Since the vessels of the root are connected with those of the stem, the nutrient water passes upwards into the vessels of the stem. This ascent may be due to root-pressure to some extent. From the stem the nutrient water is diverted rapidly to the leaves. The numerous vessels in the

wood serve to transport water as rapidly as possible. In the case of climbing plants, where the stem is very long, the

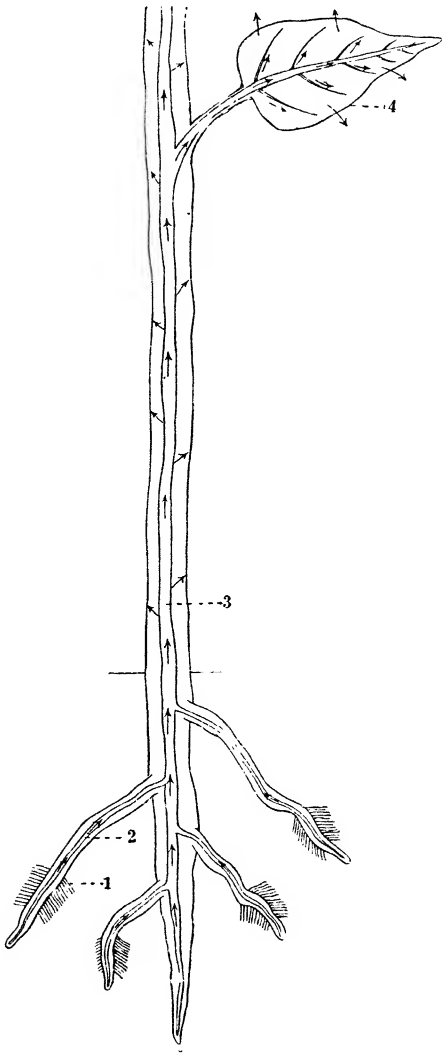


Fig. 158. Path of Water: 1. Root-hairs; 2. Vessels of the rootlet; 3. Vascular tissue of the stem; 4. Leaf. (Diagrammatic).

vessels are rather long and large. That the vessels carry the nutrient water is proved by the following experiment.

Experiment 3. Cut off a shoot from the Balsam plant and quickly let the cut-end dip into a tube containing a coloured aqueous solution, say of eosin. Place the apparatus in the sun for a few minutes. Take out the shoot and hold it up to light. You can clearly see the inner tissues, since the stem is somewhat transparent. If you observe carefully, you can see that the vascular bundles running lengthwise appear red. After a time, the coloured solution is seen to reach the leaf as is shown by the change in the colour of the ribs in the leaf. This shows that the vascular bundles carry water. Now cut a cross-section of this stem and examine it under the microscope. The vessels alone have become readily coloured showing that water passes through them.

The leaf as the transpiring organ. You have already learnt that a large quantity of nutrient water is taken to the leaf. The vessels of the leaf carry the water close to the living cells in it. How do the living cells of the leaf get water from the vessels close by ? The water in the vessels is passed osmotically from the small vessels to the living cells. The cells of the mesophyll, especially the palisade cells, receive a large quantity of the nutrient water. Such a large quantity of water is not altogether necessary and the blade is not able to retain the whole quantity. The surplus water has to be got rid of then and there. The leaves are exposed to the sun and the surplus water is converted into vapour. This water-vapour escapes into the air-spaces in the leaf. From there it escapes into the atmosphere through the stomata. This escape of water in the form of vapour from the leaves of plants is known as *transpiration.* Plants lose a large quantity of water in the form of vapour through the leaves, since the blades are large, flat and thin. The leaves should be regarded as the transpiring organs. The escape of water from plants may be easily demonstrated.

Experiment 4. Take two bottles containing water and pour a few drops of oil into each. Get two freshly cut-shoots of more or less the same length and remove the leaves from one shoot. Pass the cut-end of the leafy shoot through the

hole in the stopper and allow it to dip into water in one of the bottles and cover it with a bell-jar. Treat the other shoot in

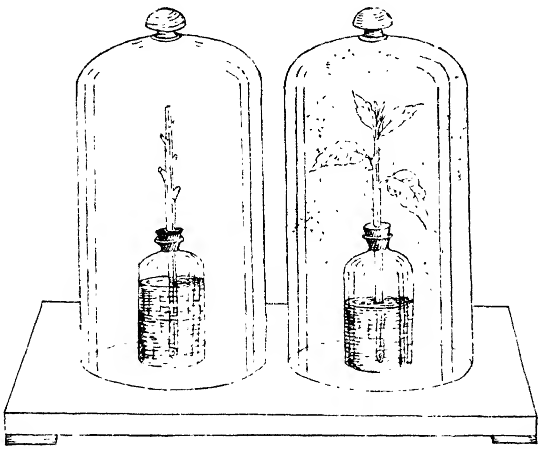


Fig. 159. Transpiration.

a similar manner. The inside of the two jars is made perfectly dry to begin with. Place the apparatus in the sun for a while. In a few minutes the inside of the jar which covers the leafy shoot gets dim and very soon drops of water begin to trickle down. There is very little change in the other jar; it may get only slightly dim. The water that appears in the jar cannot obviously have been lost directly from the bottle. Water should have been absorbed by the cut-shoot in the first place and it should have escaped from the plant. The difference which you notice between the two jars shows that water is lost almost entirely through the leaves. When the apparatus with the leafy shoot is left standing for a time, the water in the bottle will be found to be considerably reduced. Why?

Experiment 5. The importance of stomata will be demonstrated by the following simple test. Get ready an apparatus with a leafy shoot as in the previous experiment. Take

two strips of dried filter paper previously dipped in cobalt-chloride. These strips are blue when dry. Spread out one strip against the upper surface of a leaf and spread out the other against the lower surface. The two strips may be kept in position by a clip. The bit on the lower surface readily loses its blue colour and turns pink while that on the upper side remains almost unchanged. This test shows that the lower surface of the leaf transpires vigorously. This difference is really due to the presence of the stomata on the lower surface. If the lower surface of a transpiring leaf be covered with a thick coat of vaseline, very little water escapes and the part played by the stomata is made clear.

These experiments show that water is lost from the leaves in the form of vapour chiefly through the stomata. When a plant is exposed to the sun, the leaves lose water and they begin to draw fresh supply from the vessels in the stem. These vessels of the stem begin to draw water from those of the root. The root-hairs go on working and meet this demand for water created in the leaf. Owing to transpiration going on in the leaf, a continuous stream of water is kept moving right through from the root to the leaf and this current passes upwards through the vessels. Transpiration thus serves to pull up a column of water to the leaf and the current moving up the stem is called *transpiration current.* Some physiologists hold the view that the living cells close to the vessels may play some part in regard to the ascent of the nutrient water or sap. Transpiration acts as a *sucking* force and makes the column of water ascend upwards. That it can act as a sucking force is shown by the following experiment.

Experiment 6. Take a glass tube open at both ends. Fix the cut-end of a shoot air-tight to one end of the tube, fill the tube with water and arrange to let the other end of the tube dip into mercury contained in a vessel. Place the apparatus in the sun. Mercury begins to rise in the tube in a short time and continues to rise for a while. The shoot begins to transpire on exposure to the sun and absorbs water contained in the tube to make good the loss due to transpiration. Mercury

must therefore get into the tube. The rise of mercury in the tube shows that transpiration acts as a **sucking force.**

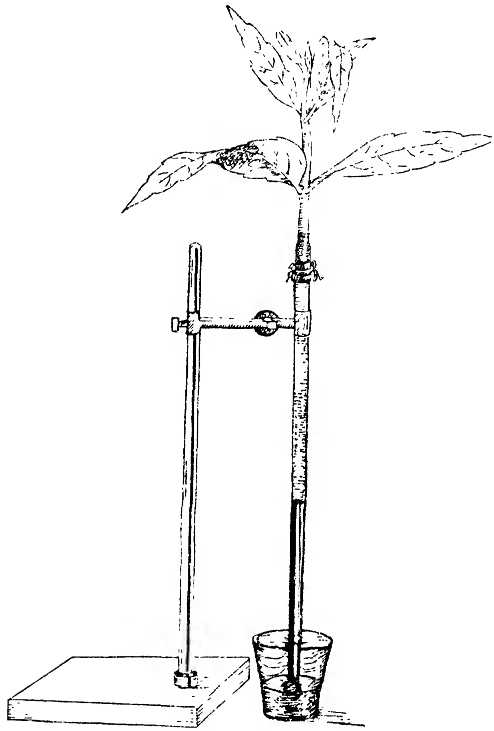


Fig. 160. Suction due to Transpiration.

The rate of transpiration is influenced by external and internal factors. It will be vigorous if the atmosphere be dry and if currents of wind should prevail. A high temperature increases the rate of transpiration. Excessive transpiration will cause injury to the plant since the loss due to transpiration cannot be made up quickly by absorption. In the afternoon, plants may lose more water and the shoots present a drooping or faded appearance. Cut off such a shoot, let the cut-end dip into a vessel containing water, and keep it in the shade for some minutes. The shoot becomes fresh. In nature the stomata close when the atmosphere becomes very dry ; and the further loss of water is thus avoided. This regulation of the loss of

water through stomata is very valuable. Plants growing on land have numerous stomata in the under surface of the leaf and they are the passages through which water vapour escapes. The size of the aperture can be altered by variations in the form of guard-cells. These are very active cells with chloroplasts and their wall is irregularly thickened. That wall of the guard-cell adjoining another epidermal cell is very thin while the wall adjoining the aperture is very much thickened at the ends. Osmotically active substances are produced in the guard-cell and water is drawn into them. When the guard-cell becomes turgid, it becomes distinctly curved owing to the irregular thickening of the wall near the aperture and the aperture remains wide open. In very dry conditions, water is lost from the guard-cells and they lose their turgidity. As a result, the curved form of the guard-cell is changed and the walls of the guard-cells adjoining the aperture are brought together so as to close the aperture practically. When the stomata are closed, the loss of water is checked and the danger of wilting is avoided. Plants growing in dry regions show variations in the disposition and structure of the stomata by means of which the loss of water from plants is effectively checked. The development of cuticle on the surface of the epidermis of the leaf minimises the loss of water.

Uses of water to plants. The importance of water to plant life is very great. Water constitutes fifty to sixty per cent of the weight of land plants. In the case of aquatic plants it may amount to more than ninety per cent. Water is necessary to keep the protoplasm active. You have also seen how it serves as the medium through which raw materials can be introduced. Water is also needed for the preparation of organic materials and it supplies hydrogen and oxygen. You have also learnt that the presence of water keeps the cells distended and makes the organs rigid.

Significance of transpiration. It may appear strange that, under such circumstances, plants should lose water at all. The loss of water is a necessary evil. There are certain advantages in transpiration. It is of special importance to plants since

it acts as a sucking force and enables a large quantity of water to be lifted up to the top of the tree. Transpiration serves to keep down the temperature around the plant.

SUMMARY

The raw food of plants consists of water and mineral salts obtained from the soil and carbon-dioxide from the atmosphere.

Water culture experiments show the indispensable nature of twelve elements in connection with the food.

The absorption of nutrient water is primarily an osmotic phenomenon and the part played by the cytoplasm in the root-hairs is significant.

Water absorbed by the root-hairs is passed on osmotically from cell to cell inwards in one direction in the root and considerable pressure is developed in the root. Consequently water gets into the vessels of the root and is forced up the vessels.

Water is carried by the vessels along the stem to the leaves and the surplus water escapes through the stomata of the leaves into the atmosphere. Transpiration acts as a sucking force and helps the column of water to be lifted up. The leaves are the transpiring organs and the structure of the flat thin blades facilitates transpiration.

The ascent of sap is chiefly due to transpiration and the co-operation of living cells is also suggested by certain investigators.

Water is of use to the plant in several ways and the loss of water from the plant-body is regulated.

CHAPTER XIV

PLANT PHYSIOLOGY: NUTRITION (*Continued*)

The leaf as an assimilating organ. The term "assimilation" is usually used in Biology in a wide sense to stand for the transformation of the food-materials into substances that can be incorporated into the protoplasm. In plants this process is done in distinct stages and each stage is, for convenience, termed *assimilation.* The first and the most important stage is the formation of carbohydrates. This process takes place only in green plants and only in the green leaves; and it is spoken of as *carbon assimilation.* The green leaf should hence be regarded as the assimilating organ. The following experiments explain the conditions under which the formation of carbohydrates can take place.

Experiment 7. Take a pot-plant of *Balsam* or Bean kept in darkness for about two days. Cover one half of the blade of a leaf with black paper. Place the plant in the sun. In the afternoon take out the leaf covered with black paper and put it in boiling water for about five minutes. Then remove it to alcohol and keep it there for a few minutes. You will see the leaf losing its green colour. The alcohol becomes green. Take out the leaf and spread it out gently in a shallow glass dish and pour iodine on it. Note the change. The portion of the blade exposed to the sun turns blue, while the other portion covered with black paper shows no such change. You know that starch turns blue with iodine. Remove another leaf wholly exposed to the sun and decolourise it as before. On treating it with iodine, it will be found that the entire blade turns blue. You can infer that starch is formed in the green leaf only when it is exposed to the sun. Any part of the leaf shut out from sunlight cannot form starch. You can have some idea of the chemical changes that take place in the leaf during the formation of starch from the following experiment.

Experiment 8. Take a beaker containing well-water and place in it a few shoots of an aquatic plant, *Hydrilla.* Invert

a funnel over the shoots and see that it is immersed in water. Fill a test-tube with water and invert it over the funnel. Place the apparatus in the sun. Arrange another apparatus of the same kind but keep it in darkness. Get ready still another, use distilled water instead of well-water and place the apparatus in the sun. Observe the difference. No change is seen in the last two apparatuses. But in the first apparatus containing well-water and kept in the sun, bubbles begin to escape in a few minutes from the shoot, and they rise up the test-tube and collect at the top. Why this difference ? The apparatus kept in darkness does not show any change because it is not exposed to the sun. The beaker containing distilled water shows no change though it is placed in the sun, because carbon-dioxide is not available. In the first apparatus, carbon-dioxide dissolved in water is available and the plant is exposed to the sun. The evolution of bubbles can thus be noticed only under certain conditions. When sufficient gas has been collected, take out the test-tube carefully and introduce into it a glowing splinter. It bursts into flame showing that the evolved gas is oxygen.

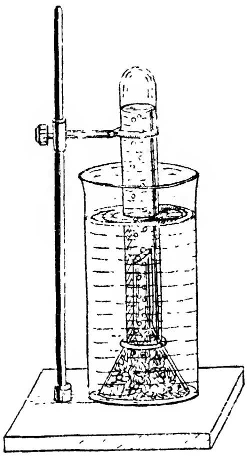


Fig. 161. Escape of oxygen.

Carbon Assimilation. Putting these results together, you may infer that green plants absorb carbon-dioxide and water and bring about chemical changes in the presence of sunlight leading to the formation of starch and evolution of free oxygen. Experiment 7 has shown that the green leaf forms starch only in the presence of sunlight. The formation of starch may therefore be regarded as the outcome of the chemical changes going on in the green cells of the leaf during the day-time. The carbohydrate consists of carbon, hydrogen and oxygen and these are contained in the water and carbon-dioxide taken to the green cells of the leaf. The details of the

chemical changes going on in the leaf are not fully known. But it has been found that the green chloroplasts in the cells of the mesophyll have the power to act on water and carbon-dioxide existing side by side in the cells of the leaf, to split them and to reunite the constituents. These changes can be brought about only when the chloroplasts can obtain the energy of the sun. It is the red and orange rays that are specially useful in this connection. The result of the chemical changes is the formation of a complex carbohydrate as an *end-product* and the evolution of oxygen as a *by-product.* The carbohydrate is kept in the cells of the leaf and the oxygen escapes into the atmosphere through the stomata. That the leaves produce a carbohydrate during sunlight is proved by iodine test described in Experiment 7. Starch produced in the leaf during the day is a very complex insoluble carbohydrate. It is argued that starch cannot have been formed directly at the first stage. Simpler carbohydrates, such as sugar, are supposed to have been formed earlier and the simple sugar is then immediately converted into insoluble starch in the leaf. Hence starch is regarded only as the *first visible product of assimilation* and the formation of a sugar is explained by the following formula :

$$6\,CO_2 + 6\,H_2O = C_6H_{12}O_6 + 6\,O_2\,.$$

The process of carbon-assimilation in the leaf depends entirely upon a supply of solar energy and on this account it is usually termed *Photosynthesis.* Starch prepared in the day is kept in the leaf till the evening and it is removed from the leaf during night. Hence leaves show little starch early in the morning. An interesting point about photosynthesis is the *locking up of solar energy* in the complex carbohydrate. Among living things it is given to *green plants* alone to prepare starch under ordinary conditions from simple inorganic materials ; and the carbohydrates prepared by the green plant form the only source of supply to animals.

Assimilation of Nitrogen. Proteins are far more complex than carbohydrates and very little is known about their production. The carbohydrates formed in the leaf and the

mineral salts left in the cells of the leaf are utilised in the preparation of proteins. There are different kinds of proteins, some of which are very complex. It is supposed that simpler

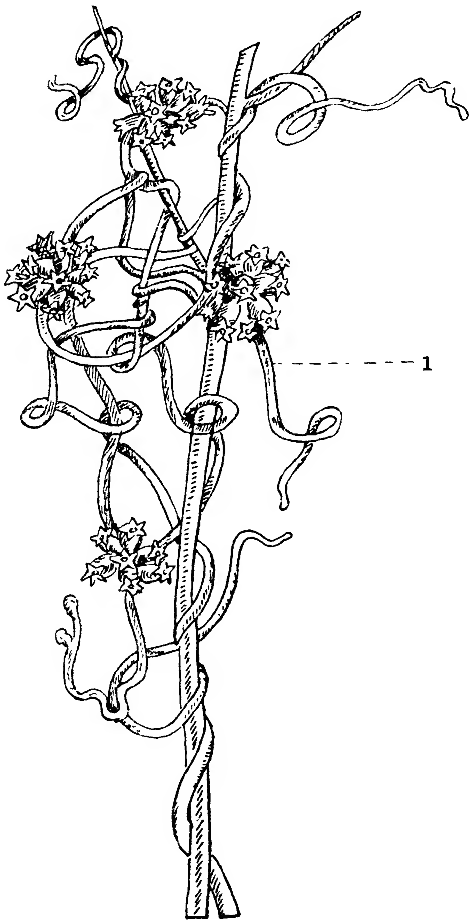


Fig. 162. Cuscuta (The Dodder): 1. Twining parasite.

proteins are formed first of all and that these are further worked up through different stages into complex proteins. The assimilation of proteins may take place chiefly in the leaf

but it may also go on in other parts. It does not depend upon sunlight.

Carbohydrates and proteins constitute the real food of plants and you have seen that these are formed from simple inorganic materials. A portion of these organic materials may undergo further changes to become part of the protoplasm. The remaining portion remains in the protoplasm of cells and is chiefly useful as materials holding energy needed by plants for carrying on their work.

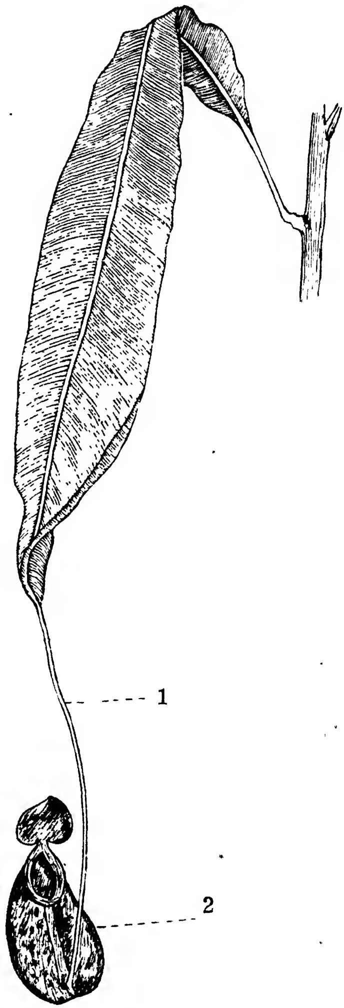


Fig. 163. The Pitcher plant: 1. Midrib prolonged; 2. Pitcher.

Special modes of nutrition. All plants which possess chlorophyll are able to prepare from simple inorganic substances complex organic foodstuff. They are able to lead an independent life and they will have to starve if they should be shut out from sunlight. There are some plants where the green pigment is not developed. The lower forms of plants belonging to the Fungi and Bacteria never show chlorophyll and their mode of nutrition should certainly be different. They have to lead a dependent life and they show many peculiarities in respect of nutrition which will be dealt with in detail later on. Even among flowering plants, may be seen a few forms like the Dodder (Fig. 162) without chlorophyll. They

are closely associated with green living plant and they obtain ready made plant food from the latter. Such dependent plants are called *parasites* and the plant which supplies materials is called the *host*. The degree of parasitism varies. Plants like the Mistletoe are not connected with the soil at all. They occur on the branches of other plants on which they depend for water and salts. These have green leaves and are able to prepare food if raw materials be given. Such plants are *partial parasites*. An interesting group of plants is the *carnivorous* or *insectivorous plants*. These have green leaves and can lead an independent life but they often trap insects and kill them so that they may use the nitrogenous substances contained in them (Fig. 163).

SUMMARY

The leaf is an assimilating organ and the chloroplasts play an important part in the assimilation of carbon known as Photosynthesis.

The green leaf utilises solar energy and is able to prepare simple carbohydrates from out of carbon-dioxide and water. The simple carbohydrates are transformed into starch which is the first visible product of assimilation.

The preparation of proteins is a complex process and it may go on in any part of the plant. But it takes place preferably in the leaf and carbohydrates and mineral salts are involved in this process.

Plants that are green can lead an independent life while plants that have no green pigment must lead a dependent life. Complex organic materials should be supplied to them. The Fungi have no chlorophyll and they lead a dependent life. Plants with green pigment may in some cases show devices for preying upon insects.

A large quantity of organic materials forming the plant food is prepared and carbohydrates, proteins and fats form the chief food stuffs present in the protoplasm. These materials contain solar energy locked up in them.

CHAPTER XV

PLANT PHYSIOLOGY : RESPIRATION

Reserve materials. Green plants prepare more carbohydrates and proteins than what may be necessary for immediate use. The organic materials manufactured by the plant are removed from the leaf and taken to other parts by the sieve-tubes of the vascular tissue. A part of the organic materials is utilised for the growth of the plant and for the formation of new rudiments. Usually a fairly large quantity of organic materials is stored up in some part of the plant-body for future use. Storage of materials is a common feature with plants. Cut the potato tuber into a few pieces and pour

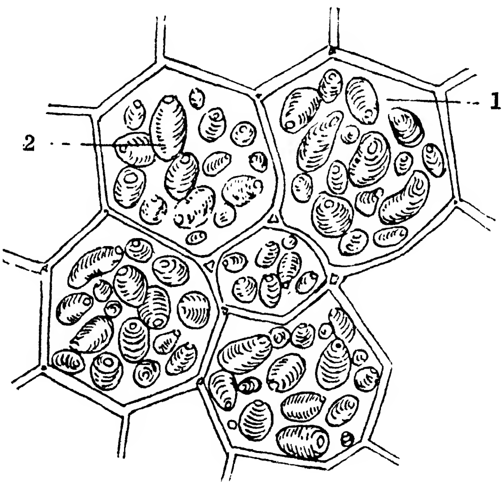


Fig. 164. Reserve materials in the Potato : 1. A cell ; 2. Starch grains.

a few drops of iodine on the cut-surface. The surface turns blue showing the presence of starch. Examine a thin section of the potato under the microscope. You will see starch inside the cells in the form of grains. Take a thin slice from the fleshy mass of the bean seed and the cells show similar starch grains. The wood-parenchyma of trees occurring along with

the vessels very often stores up materials. Tubers, rhizomes, seeds, and the parenchyma in the wood of trees act as store-houses of reserve materials. The nature of the reserve material is not the same in all cases. Starch is one kind of reserve material. Oil is another kind found in Castor seeds and Coconuts. Proteins are also found as reserve material in the protoplasm of cells and they may be abundant in certain special cells. The reserve materials are made use of, when buds begin to develop or when flowers are about to be formed, or when seeds begin to germinate. They exist generally in an insoluble form and they cannot leave the cells of the storage tissue unless they are converted into soluble and diffusible substances.

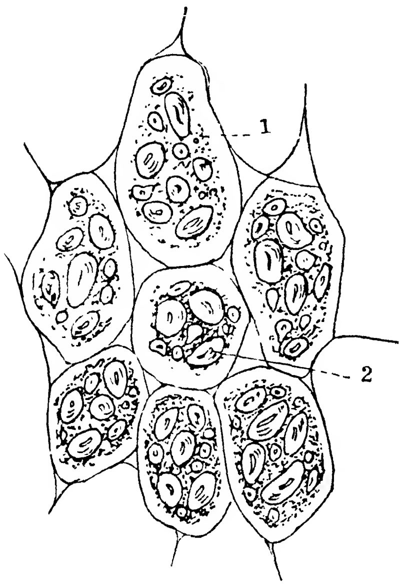


Fig. 165. Reserve materials in the Bean seed : 1. A cell ; 2. Starch grains.

Enzymes and their action. This transformation of the insoluble material is not unlike the digestive process in animals and it is brought about by special bodies known as *enzymes*. Ordinarily there is no digestive activity in plants since the materials are simple to start with. When, however, complex organic materials contained in cells, have to be utilised directly as food by buds and flowers, they have to be presented in a form suitable for absorption. The enzymes which act on reserve materials are produced by the protoplasm of the cells of the store-house and they show remarkable powers. They are able to convert a large quantity of organic materials without themselves undergoing any change. A small quantity of enzyme is enough to bring about the change.

There are different kinds of enzymes and each of these can act only on a particular substance. *Diastase* is a common enzyme produced in the different parts of plants and it can act only on starch. It converts starch into sugar. There are enzymes like the *Proteases* which can act on proteins alone; and the *lipase* acts on fat.

Respiration. You have learnt that a portion of the organic material is used for growth and storage. But a good portion of the carbohydrates is being constantly used up during respiration. It now remains for us to study *Respiration* in plants.

Respiration in plants is essentially the same thing as respiration in animals. In the absence of free oxygen of the atmosphere, plants also are unable to live. That respiration is going on in plants can be shown by proving that oxygen is taken in and that carbon-dioxide is given off.

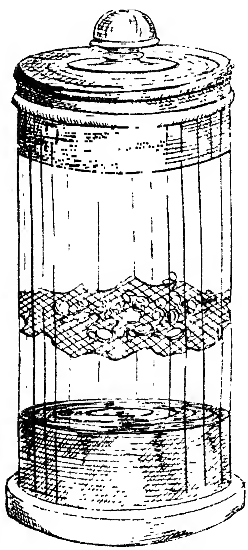


Fig. 166. Respiration.

Experiment 9. Take a jar containing clear lime-water. Thrust a piece of wire-gauze into the jar and let it stick to the sides of the jar. Let not the wire-gauze touch the lime-water. Place a few germinating Bean seeds on the wire-gauze and cover them with wet blotting-paper. Close the jar air-tight. In a short time the lime-water turns milky and this shows that carbon-dioxide is given off by the germinating seeds. Open the jar and introduce a burning taper. It goes out. You can now infer that oxygen has been taken in and carbon-dioxide is given off by the germinating seeds.

Experiment 10. Take two tubes of the form shown in Fig. 167. These tubes are open at both ends. Introduce tender shoots or flowers into the broad part of the tube. Suspend

a small tube containing caustic potash in the broad part of one of the tubes. Let the narrow end of each tube be made to dip into a tumbler containing water. See that the stoppers are air-tight. If you are using tender shoots for the experiment, the apparatuses must be kept in darkness (why ?); if exposed to light they must be covered with black cloth to prevent photosynthesis and to avoid complication. In half an hour you can see a distinct difference. Water begins to rise in the apparatus in which caustic potash is placed. There is no change in the level of water in the other apparatus. The preceding experiment has proved that carbon-dioxide is produced, and you know that caustic potash absorbs carbon-dioxide. In this experiment the shoots or flowers take in the oxygen in the tube and give off carbon-dioxide. In the case of the apparatus where caustic potash has not been introduced, the carbon-dioxide given off replaces the oxygen in the tube and no change in level is possible. In the other tube, the carbon-dioxide given off is itself absorbed by caustic potash. Hence water rises in the tube.

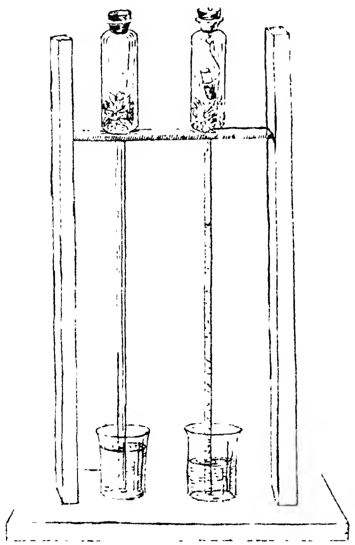


Fig. 167. Respiration in plants.

These two experiments show clearly that oxygen is taken in by plants and that carbon-dioxide is given off. **Germinating seeds, green shoots, flowers and every part of the plant-body containing living cells can be shown to be respiring.** The exchange of gases is the same in plants as in animals. The manner in which the exchange is brought about cannot but be different. Oxygen of the atmosphere enters the leaf through the stomata and fills up the air-spaces in the leaf. From these air-spaces it diffuses gradually into the cells of the leaf and also into the numerous minute air-spaces in the

tissues of the stem and the root. All the air-spaces in the tissues of the plant-body form one common ventilating system communicating with the atmosphere through the stomata. Oxygen that has reached the air-spaces diffuses into the adjoining living cells. What happens in the living cells when oxygen reaches them is not definitely known. The absorption of oxygen is always accompanied by the breaking down of organic materials. The carbohydrates are broken down or oxidised, and carbon-dioxide and water are always produced. The escape of water during respiration cannot be noticed easily. But carbon-dioxide escapes from the living cells into the adjoining air-spaces and finally gets out into the atmosphere through the stomata. Respiration may be regarded by some as a slow combustion process since organic materials are oxidised. **It is really a vital process going on in all living cells**

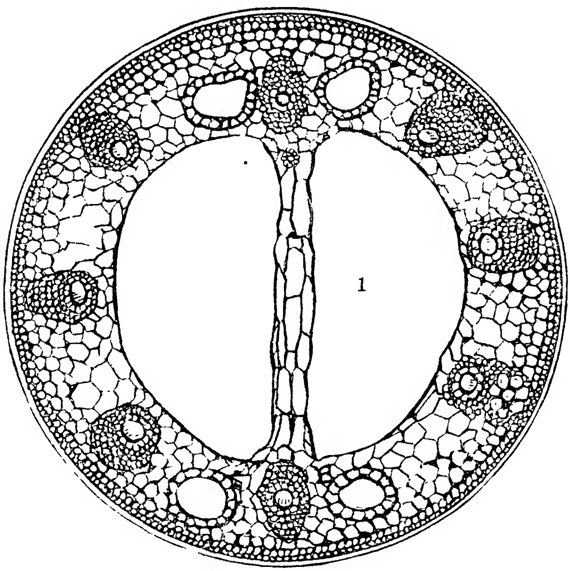


Fig. 168. C. S. of the Petiole of the Lotus plant : 1. Air-cavity.

situated in any part of the plant-body. It is vigorous in young active organs and also in organs doing work. It is an uninterrupted process going on throughout day and night and

throughout the body. The chemical activity resulting in the breaking down of organic materials during respiration is spoken of as *Katabolism* while the constructive phase leading up to the formation of organic materials during assimilation is known as *Anabolism.* These two sets of chemical activities going on in the body of living things constitute *Metabolism.*

Ordinarily, the exchange of gases takes place chiefly through the stomata of the leaf. This exchange may be found to be far too slow. Roots which are placed far away from the leaves manage to get oxygen also directly from the air in the soil. In the case of large shrubs and trees, the lenticels are also useful in bringing about the exchange of gases. Special devices for aeration are necessary in the case of plants occurring in water-logged situations which are distinctly poor in oxygen. Special breathing roots are seen to grow up against gravity and take part in the exchange of gases. The problem of aeration is somewhat difficult in aquatic plants. These show large air-cavities which act as reservoir of air.

Respiration must result in the loss of organic materials since these are broken down into simpler substances like carbon-dioxide and water. There must certainly be a loss in weight during respiration since the products of decomposition leave the plant. You may ask what advantage is gained by the destruction of organic materials in the plant tissues. You have already learnt that the organic materials possess, in addition to **food-value, considerable energy-value.** Solar energy is, as it were, locked up in these materials and it is in a potential form. Living plants are very active and their organs are constantly doing work. The roots grow down, the stem grows up, the leaves and the flowers open and close, and food-materials are taken to and fro. How can plants do their work if energy be not made available ? Wherefrom can this energy be derived ? The living cell of plants contains energy-containing carbohydrates. During respiration these are broken down completely into simple substances. At that moment the energy locked up in them is released and placed at the disposal of the organs of the plant-body. It is this energy that is utilised by organs while doing work and the signi-

ficance of respiration becomes obvious. Are you not utilising the energy held up in plants when you are using them as fuel ? The energy released during respiration escapes as heat to some extent.

Experiment 11. Place a number of flowers in a vessel. Take a bell-jar with a thermometer passing through the hole in the stopper. Cover the vessel with the bell-jar so that the bulb of the thermometer dips into the flowers. Get ready a similar apparatus without flowers. The temperature becomes higher in the former case showing that heat is produced by the respiring flowers.

Experiment 12. Can air get into the leaf through the stomata ? Take a narrow-mouthed bottle provided with a two-holed stopper. Half fill the bottle with water. Through

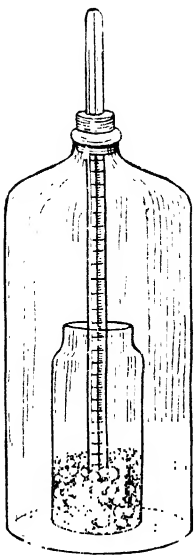


Fig. 169. Heat during respiration.

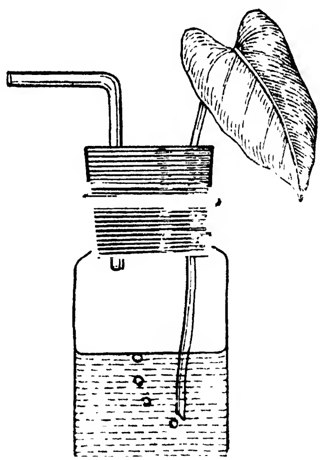


Fig. 170. Entrance of air through the leaf.

one hole insert the petiole of a broad leaf, and see that the petiole dips into the water. Pass a tube bent at right angles through the other hole and see that the inner end of the tube

is clearly above the level of the water. The stopper, the bent-tube and the petiole should be fixed air-tight. Draw out the air in the bottle. Bubbles begin to appear at the cut-end of the petiole and rise up the water in the bottle as air is drawn out. Every time air is drawn out, a series of bubbles appear. This is due to the fact that the air from the atmosphere is forced into the leaf through the stomata. This air diffuses into the air-spaces and finally appears as bubbles at the cut-end. Cover the leaf in the apparatus with a thick coat of vaseline. Bubbles do not appear. Why ?

Abnormal respiration. Plants depend upon the free oxygen of the atmosphere for their respiration. In the absence of free oxygen, the life of the plant comes to an end. This normal respiration in plants is known as *Aerobic* respiration and the organic material is completely oxidised resulting in the release of energy. The waste products that are produced are carbon-dioxide and water. There are certain plants like the Bacteria which can live in the absence of free oxygen of the atmosphere. Even in higher plants, respiratory activity can be noticed and carbon-dioxide may be produced for a time even when no free oxygen is available. Such a respiration is called *Anaerobic* respiration or *Intra-molecular* respiration. Organisms showing aerobic respiration are known as *Aerobes* and those adopting anaerobic respiration are known as *Anaerobes*. One chief point about the anaerobic respiration is the *incomplete decomposition of the carbohydrate*. It is split up into alcohol and carbon-dioxide. Some

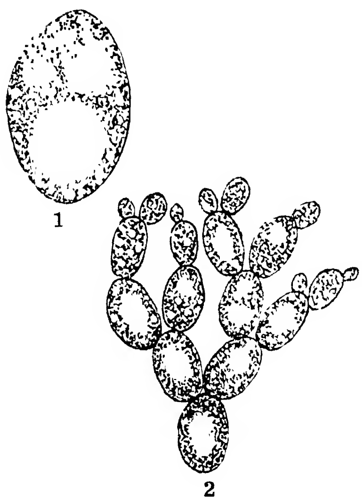


Fig. 171. Yeast : 1. The unicellular organism ; 2. Budding under favourable conditions.

energy is no doubt released and utilised but the products of decomposition are yet complex. The decomposition of the carbohydrate into alcohol and carbon-dioxide brought about by the yeast is due to anaerobic respiration and the fermentative activity of micro-organisms usually called "fermentation" should be regarded as anaerobic respiration.

SUMMARY

The surplus organic materials are stored up in the different parts of the plant-body and they have to be digested or converted into diffusible and soluble substances when they have to be utilised.

There is something like a digestive process noticed in store-houses and this is due to the activity of a number of enzymes secreted by the protoplasm.

The enzymes are complex bodies and are able to convert a large quantity of organic materials without themselves undergoing any change.

Respiration is as much a vital activity in plants as in animals. Plants require free oxygen and give off carbon-dioxide.

The exchange of gases is possible through the system of numerous inter-cellular spaces in the plant body which communicate with the atmosphere through stomata. Lenticels are also valuable in this connection.

During respiration the carbohydrates are broken down and carbon-dioxide and water are produced. Energy locked up in carbohydrates is also released and the purpose of respiration is to release the potential energy in carbohydrates and make it available for the activities of plant organs.

Respiration goes on in all living cells throughout the plant body all the twenty-four hours and is an uninterrupted process.

Respiration depending on free oxygen is the normal or aerobic respiration. Respiration in the absence of the free oxygen is possible in certain groups and this is called anaerobic respiration.

CHAPTER XVI

PLANT PHYSIOLOGY: GROWTH

What is Growth. A germinating mango seed produces a seedling. In course of time the seedling becomes a big tree with a stout trunk. Its roots are spreading everywhere in the soil and the crown of branches is attractive. You say that the Mango plant has been growing. What does it mean? It means a considerable increase in size and an addition of new structures. Growth thus shows itself in an increase in size and in the addition of new parts. Further, the growing organs show a tendency for differentiation into tissues. One who looks at a seedling hour after hour may not appreciate the extent of growth because it is imperceptible. But the growth of the plant becomes plain in course of time.

Conditions of Growth. Growth of a plant is possible only under certain favourable conditions. The enlargement of the body and the production of new structures require plenty of organic material without which no growth can take place. The presence of water in young growing organs is very favourable for growth. The cells in the growing organ are stretched owing to the large quantity of water present in them and thus growth is helped. There are several factors which influence the growth of plants in different ways. They may influence the form and structure of an organ, or the rate of its growth or the direction of its growth. Growth is very marked between 25° C. and 30° C. The influence of light on growth is remarkable. The etiolated condition of plants which has already been referred to is noticed in plants grown in the dark. Very few plants are accustomed to grow in the shade and these show large blades. The leaves of plants which grow in the sun are small and the palisade tissue is well-developed in them.

Growing points and growing regions. Though the plant continues to grow for a long time, every bit of it need not

and does not, continue to show signs of growth. The leaf completes its growth very soon and it reaches its limit in a few days. The stem and the root continue to grow no doubt but, even in these organs, the old parts are not growing. Three regions may be roughly recognised in these two organs. For instance, in the root, there is the tip which is a small region producing new cells needed for the construction of the body. This region is to be regarded as the *formative part* and the *formation phase* forms the first phase of growth. A section of the root will show that the region behind the tip is characterised by a tendency on the part of the newly formed cells to elongate remarkably. This region of elongating cells forms but a short region extending to about 10 mm. behind the tip in soil roots and it is clear that the cells produced by the formative region pass through an *elongation phase.* Farther away behind the tip, the root is characterised by the differentiation into tissues. This differentiation into tissues forms the third phase of growth. The actual elongating region is thus localised in roots and stems and it is a very short region, especially in the root.

Let us take a few germinating bean seeds whose radicles have grown in length. Let the radicles be divided into close and equal intervals by dots of India ink and let them be allowed to grow. If the radicles be observed after some hours, the few intervals immediately behind the tip have become longer compared with those farther away from the tip. These few intervals behind the tip should be regarded as the growing or elongating region which is short. A short growing region is advantageous to a root which has to make its way downwards through the soil. A shoot also shows behind the apex a similarly localised growing region which is longer than that of the root. A longer growing region is not a disadvantage for a shoot growing up in air.

SUMMARY

Growth manifests itself in an increase in size, in the addition of new rudiments and in the differentiation into tissues.

Growth is possible only under certain favourable conditions and several factors influence the rate of growth, the direction of growth and also the form and structure.

Growth is confined to the free end of the root and the shoot. There are three phases in growth, the phase of formation, the phase of elongation, and the phase of differentiation.

The growing region of the shoot is very short but it is slightly longer in the case of the shoot.

CHAPTER XVII

PLANT PHYSIOLOGY: MOVEMENTS

Movements in Plants. Animals are most of them moving from place to place and movements are regarded as a common feature of animals. Plants are no doubt stationary and remain rooted to the soil. Yet, it should not be supposed that they do not show movements. There are a few forms of plants like the Bacteria and primitive Algae which can move from place to place. Movements need not always be in the nature of locomotion. A living thing may remain in one place but may have its organs moved in space. Movement of organs is very common in plants.

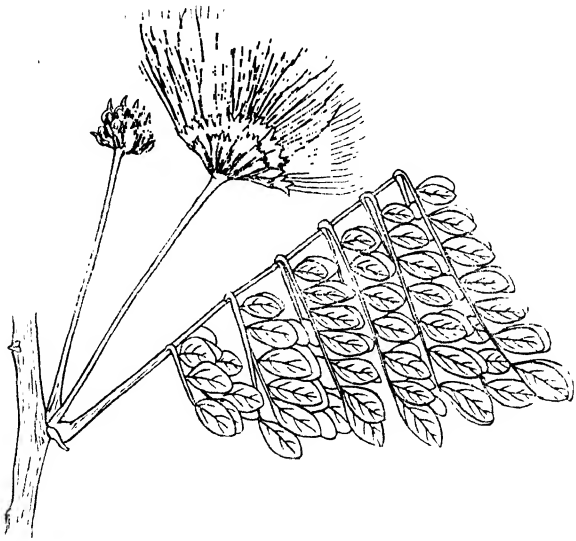


Fig. 172. The Rain tree : Sleep-movement.

The flowers of the Lotus and the Water-lily open in the morning and close in the evening and such activities represent movements. The leaves of the Rain tree are spread out in the day while they present a sleeping or closed posture in the night. The assumption of different postures is certainly a movement. What about the unfolding of a leaf, say of the Plantain leaf ? Is it not an instance of movement ?

Two Kinds of Movements. Movements may be due to internal causes in the protoplasm and such movements are known as *Autonomous or spontaneous* movements. In the cells of the leaf of *Hydrilla* and in the young cells of a plant called *Chara,* movement of the protoplasm is clearly seen under the microscope. Many of the movements of plants are, however, due to the influence of external factors and these movements are therefore known as *paratonic* or *induced* movements.

Tropism. External factors, such as variations in temperature and humidity irritate the protoplasm of living cells and compel it to adjust itself to these changes. Such factors as act on the protoplasm and irritate it are called *Stimuli.* Thus, gravity, sunlight and mechanical contact can, each of them, act as a stimulus. The protoplasm which happens to be influenced by one or other of the above-mentioned stimuli, begins to react and to adjust itself. This adjustment is called *Response* which usually takes the form of movements of organs. The stimulus may be applied or perceived at one point and the part that responds may be away from it. The stimulus is then transmitted from the place of perception to the place of response. Movements of an attached organ are usually brought about by a slight curvature of the organ. When the influence of a stimulus happens to be one-sided, the organ curves in a definite manner in relation to the direction of action of the stimulus; and the direction of the organ can thus be turned. Such movements bearing a definite relation to the direction of the stimulus are called *Tropisms.* The tropism due to gravity is called *Geotropism* and the tropism due to sunlight is known as *Heliotropism* or *Phototropism.*

Geotropism

Experiment 13. How is it that the root always grows downwards and the shoot grows upwards everywhere? This vertical growth of the root and the shoot is regarded as normal. Suppose this normal position is disturbed. Take a pot-plant and keep it in a horizontal position for a time. Observe what

happens. The shoot manages to grow up vertically after a time. Observe that the older part of the shoot continues to be horizontal and that the growing portion of the shoot alone is brought into a vertical position and made to grow up. How has the direction been turned ? Notice the sharp curvature

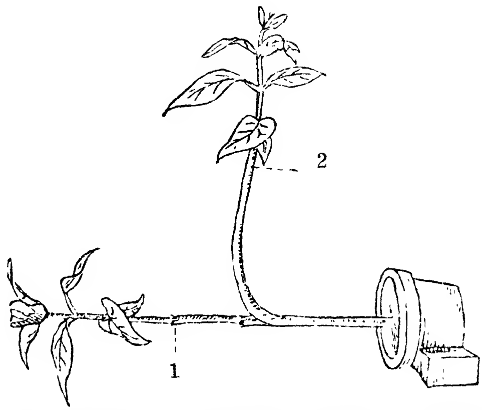


Fig. 173. Geotropism : 1. Horizontal position ; 2. Vertical position.

of the stem. The upward movement of the shoot kept in a horizontal position has been brought about by a curvature at the growing region of the stem. This curvature at the growing region is due to the one-sided influence of gravity acting on the horizontal shoot. Gravity induces more vigorous growth on the lower side of the horizontally placed stem at the growing region. By inducing unequal growth on the opposite sides of the growing region of the stem, a curvature is brought about and the stem moves up against gravity. Since the curvature is seen only close to the growing region, the older portion remains horizontal and the younger part alone grows up against gravity. Whenever the normal direction of the shoot is interfered with, the stimulus of gravity will be felt and the shoot will grow up vertically against gravity by curving upwards. Because the shoots grow against gravity they are said to be *negatively geotropic*. Look at the branch shoots of any plant in the field. They may be more or less horizontal but the stem near the growing region is curved so as to make the terminal region grow up in a vertical direction against gravity.

Experiment 14. Take a germination box. (Any box with a glass front will be sufficient for our purpose). Place a few seedlings inside the box against the glass pane. See that some of the seedlings are placed in a horizontal position and that the rest are kept in the normal position. Gently fill up the box with sand so as not to disturb the arrangement of the seedlings. Those kept in a horizontal position are stimulated by gravity and the root as well as the shoot shows geotropic movement. Notice the root. There is a curvature of the growing region behind the tip and the direction of curvature of the root is the reverse of what is seen in the shoot. The root becomes vertical but **curves downwards.** Here gravity induces more vigorous growth on the upper side of the growing region of the root with the result that the root curves down. Look at the seedlings placed horizontally. The shoot-end curves up and the root-end curves down while the older part is remaining horizontal. This is due to the fact that curvature takes place only at the growing region in each case. Roots which grow down towards gravity are said to be *positively geotropic.*

Heliotropism

Experiment 15. Take a pot of seedlings. Place the pot close to the window inside a room so as to face the open space outside. At first all seedlings are quite straight. In a short time the influence of sunlight acting from one direction can be clearly seen. Sunlight is received from the open space and the side of the plant away from the window is shut out from light. The stems of seedlings curve near the growing region towards the open space. The shaded side is, for the time being, growing more vigorously while the illuminated side is somewhat slack. Hence a curvature is perceptible and the shoot

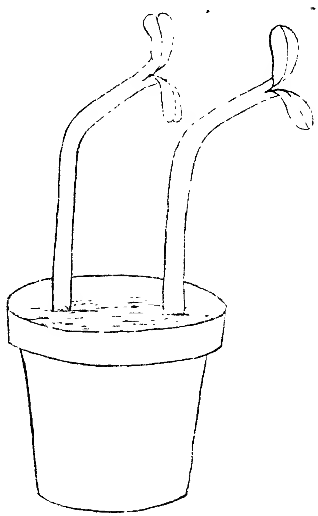


Fig. 174. Heliotropism.

bends or moves towards sunlight. Shoots are said to be *positively heliotropic* since they curve towards the sun. Roots on the other hand move away from sunlight and are said to be *negatively heliotropic.* Look at the leaves. They are placing themselves at right angles to the rays of light and they are described as *transversely heliotropic.*

Advantage of tropic movements. Gravity and sunlight act on plant organs by inducing unequal growth on opposite sides of the growing region of the root and the stem. On account of these stimuli the plant organs are compelled to grow in a definite direction. The tropic movements due to these stimuli are highly advantageous to the plant. The farmer sows his seeds at random and the roots are not placed always in a proper position. Owing to the stimulus of gravity the roots must curve down if they do not happen to be in the normal position. They are forced to grow beneath the soil and do their work. Similarly the bending of the shoot towards light is a great advantage.

Other movements. Organs which have completed their growth may also show a capacity for movements. Leaves which have stopped growing may show peculiar movements when acted upon by stimuli. Take the Sensitive plant. Give a gentle blow to a leaf. The leaflets begin to close. If the blow be somewhat severe, the whole leaf will begin to fall and present a drooping appearance. Even the adjoining leaves may take part and show a tendency to fall. It is obvious that the stimulus has been perceived and then transmitted further. After a few seconds there is a response in the form of a movement of the leaves. If the plant be left at this stage undisturbed for a few minutes, it will recover and the leaves resume the normal posture. How has the leaf of the sensitive plant been moved ? The stalk or petiole of the leaf shows at the base a thick cushion called *pulvinus.* Movement is brought about by difference in the turgidity of the opposite sides of the pulvinus. The presence of a pulvinus in the sensitive plant enables it to respond readily and the movement is thus made clearly visible to the naked eye. On this account the Sensitive plant is usually called an irritable plant. Strictly

speaking, all plants are irritable as has been clearly demonstrated by Sir Jagadish Chunder Bose. In the ordinary plant the response is very feeble and cannot be observed with the

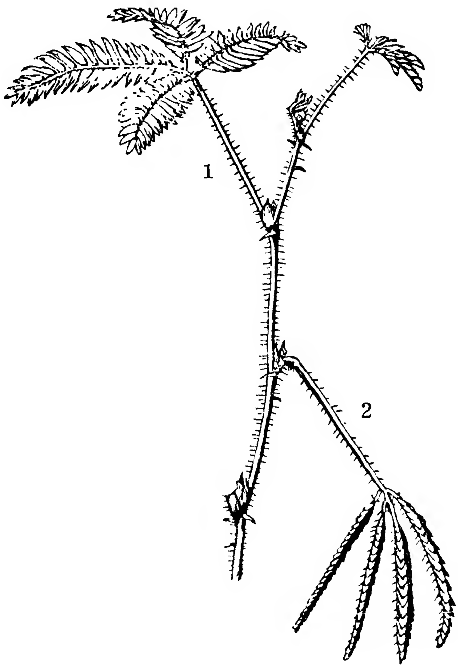


Fig. 175. The Sensitive plant : 1. Unstimulated ; 2. Stimulated.

naked eye. Many plants belonging to the Bean family show what are popularly known as *sleep movements*. Look at the Rain tree common on the roadside. In the morning the leaves are more or less erect and the leaflets are spread out. This is the *day-position*. Towards evening the leaflets close and the pinnae hang down. The leaves seem to have gone to sleep and hence the name—sleep movements. The closed-position is the *night-position*. These sleep movements are due to changes in external conditions and are made possible through variations in the turgidity of the pulvinus.

SUMMARY

Plants may be stationary generally, but microscopic forms are able to move from place to place. Organs of plants are capable of being moved in space.

Movements may be spoken of as autonomous and induced movements.

Induced movements are common in plants and several external factors such as gravity, sunlight, chemicals, contact, moisture, etc., can act as stimuli and their influence is perceived and transmitted.

A response follows the application of a stimulus and takes the form of a movement. The movement of an organ is made by the curvature of the organ. Where the direction of an organ is influenced by the direction of action of the stimulus, the movement is known as *Tropism.* Tropisms like Geotropism and Heliotropism are advantageous.

Sleep-movements are a common feature noticed in leguminous plants; and the so-called irritable plants like the Sensitive plant possess a convenient mechanism like pulvinus helping the leaves to respond quickly. All plants are irritable.

CHAPTER XVIII

PLANT PHYSIOLOGY: REPRODUCTION

The Individual and the Race. The organs of a plant are, as pointed out already in a previous chapter, divided into two kinds, vegetative and reproductive. The vegetative organs are of direct use to the individual while the reproductive organ is a provision for the perpetuation of the race.

Kinds of Reproduction. Methods of propagation are as varied as the forms of plant-life. Special features in the reproduction of plants will be dealt with in detail when the life-history of the different forms of plants is considered. All modes of propagation can be brought under two general heads. (1) Vegetative or Asexual reproduction, and (2) Sexual reproduction. In the vegetative propagation, a part of the plant-body happens to be separated and it is found to develop into a new individual exactly like the original individual. There is only one individual concerned in this mode and the vegetative or asexual mode is known as *monogenetic.* The part that is detached may be a small little cell or a big cutting. Some biologists would make a distinction between vegetative and asexual reproduction. They would prefer to restrict the term "Vegetative" to the type where no great change in the protoplast is involved in the formation of the germ-body as in cuttings for instance. The term "Asexual" is applied by them to the type where the germ body is produced as the result of a marked change in the protoplast as in the formation of spores. It may be convenient to consider the vegetative mode as distinct from the asexual mode. The sexual mode is more complex and it consists in the *union of two sex-cells* or *gametes.* Since two sex-cells are concerned in this process, the sexual mode is described as *digenetic.*

(1) *Vegetative method.* In minute primitive plants like the Bacteria to be described later on, the body consisting of a single cell divides into two which separate from each other and lead an independent life. This primitive method is merely

a cell-division. Usually, vegetative propagation is effected in higher plants by means of cuttings. A gardener takes a cutting of the Rose or the Croton and plants it carefully. In a few days adventitious roots arise from the cutting and fix it to the soil while the dormant buds on the cutting now find it easy to develop into shoots. Thus a new individual is easily produced. In agriculture and horticulture, this method of propagation has become so common that forms like the Plantain are propagated only vegetatively. Subterranean shoots like the rhizome, tuber, corm and bulb are well-fitted as organs of vegetative propagation. They have buds and there is provision of ample material for their development. Leaves of *Bryophyllum* and *Scilla* which are very thick can produce buds easily and can be used for propagation. Fleshy buds or bulbs

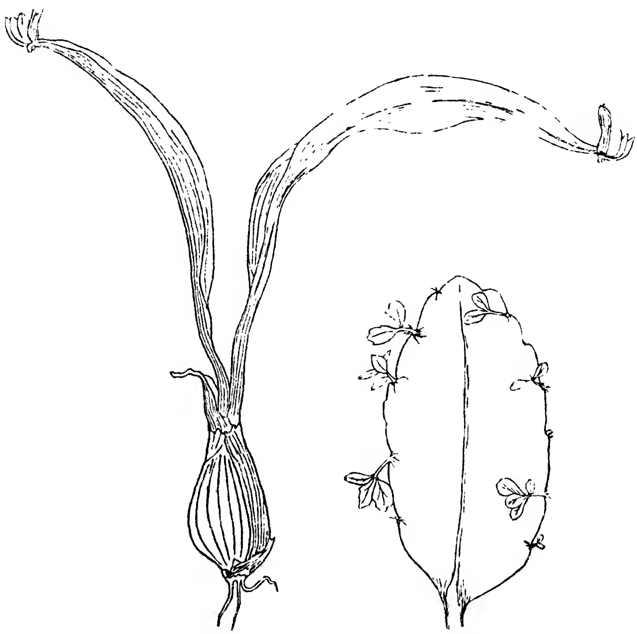


Fig. 176. Vegetative propagation : a. Bryophyllum ; b. Scilla.

are sometimes developed on the flowering shoots in *Agave* and Onion and these are known as *bulbils*. The bulbils of *Agave* which are fairly large and fleshy are produced in large numbers and are good for propagation.

(2) *Asexual Method.* In some of the lower plants like the Fungi and the Algae to be considered later, the asexual reproduction takes place easily and extensively by means of germ-bodies known as *spores.* The spores are minute cells and they directly produce an individual exactly like the parent on leaving the parent-plant.

Sexual Reproduction. This mode occurs along with other methods in almost all forms of plants but there are striking differences in details; but *the fusion of two gametes is a constant feature.* In the absence of union or fusion, neither of the two gametes can show any sign of development into a new individual. If the gametes that fuse, happen to be similar in form, the sexual union is known as *Conjugation* and this is common in some primitive forms. The product of such sexual union is known as *Zygote.* In most of the plants, the gametes are differentiated into a small male gamete or *sperm* and a slightly bigger female gamete or *egg.* The union between two such dissimilar gametes is called *Fertilisation.* This union of gametes acts as a great stimulus and the zygote or fertilised-egg can show activity. One feature in the reproduction of higher plants is noteworthy. The production of asexual spores is also a constant feature in them, but it does not take place on the same individual or generation that produces the sexual gametes. The two generations always occur separately one after another in regular succession in the life-history of the plant. This peculiar feature is known as the *alternation of generations* and it will be dealt with fully in connection with the Mosses and Ferns.

Work of the Flower. The flower is a highly specialised reproductive structure. It is considered separately, merely because it shows several interesting features. The flower is intended to produce asexually the germ-bodies or spores. The pollen grain is one kind of germ-body consisting of a single-cell and it is produced in the chambers of the anther. It is really a small germinating spore which leaves the anther. The ovule produces another kind of germ-body or spore which is bigger. This spore never leaves the ovule but undergoes changes before fertilisation takes place. Changes continue to

take place in the pollen grain when it is brought into contact with the stigma of the flower. If fertilisation should take place, it is essential that the pollen should be carried from the anther and deposited on the stigma of the flower. This preliminary process of the transport of pollen and deposition of the same on the stigma is known as *Pollination.* Many of the features of the flower have something or other to do with pollination. The pollen grain cannot find its way itself to the stigma but it has to be carried by an external agent. The stigma which is placed at the tip of the style is able to receive the pollen brought from outside. It is likely that pollen grains from a flower may reach the stigma of the same flower. It is also possible that pollen grains from other flowers either on the same plant or on the same kind of plant may reach the stigma. Sometimes pollen grains from flowers belonging to quite a different kind of plant may also be deposited on the stigma. Ordinarily, pollen grains belonging to a different kind of plant may be of no avail. Pollen grains of the same flower are likewise found to be ineffective generally. Pollen grains of a flower will prove useful if they should be deposited on the stigma of another flower on the same plant or on the same kind of plant. Such pollination is described as *cross-pollination.* This seems to be very common in nature. In some cases, the pollen of a flower may be used to fertilise the ovule of the same flower. Such pollination is known as *Self-pollination.* Self-pollination is prevented and cross-pollination is encouraged in nature since cross-pollination is found to result in better progeny. The structure of the flower is such as to encourage crossing and to prevent self-pollination. In plants like the Palms, the Pumpkin and so on, possessing unisexual flowers, self-pollination is out of question. Even in the case of bisexual flowers where the stamens and the pistil are close together, cross-pollination is aimed at. In several cases, the stigma is far away from the anther and there is no chance of the pollen reaching the stigma of the same flower. In some plants like *Clerodendron,* the stamens are in the centre of the flower at the time of the opening of the flower while the style is inclined to one side. Some hours later, the stamens gradually move away from the centre and conceal themselves

beneath the corolla lobes but the style now comes to the centre and exposes fully the receptive part of the stigma. This interchange of position of the reproductive parts prevents self-pollination and encourages cross-pollination. Another feature which prevents self-pollination is the phenomenon known as *dichogamy* i.e., the maturation of the anther and the stigma at different times. When the anther is ripe and the pollen grains are ready to leave the flower, the stigma of that flower is not in a position to receive them. On account of these peculiarities, it is necessary that the pollen has to be transported from flower to flower. The distance may not be great in many cases but still some agent should be employed to transport the pollen. The distance will be great in the case of dioecious flowers where the staminate flowers occur on one plant and pistillate flowers on quite a different plant as in the Palmyra. The need for an external agent is clear under any circumstance.

Agents for pollination. (a) Wind. Wind is useful as an agent of pollination. Wind-pollinated flowers are found in grasses and these are described as *anemophilous.* In these flowers the pollen should be free to leave the flower easily and the stigma should be able to catch stray pollen grains. The floral coverings are usually much reduced in these flowers and the anther protrudes outside. Pollen grains which are in the nature of dry particles are easily removed from the anther and carried away by wind. The stigma is also protruding outside and in the grasses it takes the form of a brush-like body with numerous hairs. Thus the receptive surface of the stigma is increased. It is likely that many of the pollen grains may not reach the stigma. Hence in these plants the output of pollen grains should be very large.

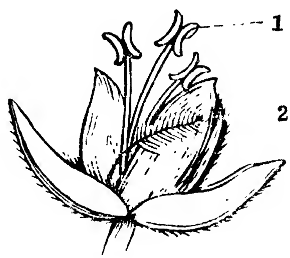


Fig. 177. Wind-pollination (A grass): 1. Exserted anthers; 2. Hairy stigma.

(b) Animals. These render valuable service as pollinating agents. Among animals, it is the insects that play an important part. Small birds may sometimes act as pollinating

agents. *Insect-pollination* is very common and insect-pollinated flowers are described as *entomophilous*. See how the garden is visited by insects when plants are in flower. Insect-pollinated flowers show some striking features. They develop bright colours which make the flowers conspicuous and serve to attract insects. The bright colour of petals shines by

Fig. 178. Insect visiting the flower (Crotalaria).

contrast with the green leaves. If flowers happen to be small, they are borne in clusters as in the Sunflower and thus made more conspicuous. In the case of flowers like the Jasmine and *Nyctanthes* which open in twilight, their odour makes them conspicuous. Insects which visit flowers are detained in the flower for a time. Observe the different forms of petals in nature. You may see how insects may find in the corolla a place of refuge or shelter, or comfortable seat. Substantial inducement in the form of liquid food or honey is also offered to insects and hence they are frequently seen to visit flowers. The honey is produced at the base of the flower and it is concealed by the petals. The insect has to pass by the side of the anther and the stigma while it is inside the flower to get at the honey. Its body will be frequently rubbed against the essential organs. Usually the anther ripens earlier and its pollen grains are ready for transport. Suppose an insect visits a flower that has just now opened. Its body will touch the anther when it moves inside the flower. As it leaves the flower, its body appears golden yellow owing to the mass of pollen grains. When it visits another flower that

has opened a little earlier, the stigma is ripe enough to receive the pollen. When the body happens to touch the stigma, some of the pollen grains are removed and they stick to the stigma. Insects are very active and visit a number of flowers in quick succession. They can therefore effect cross-pollination more certainly than wind. The output of pollen in these flowers is much reduced but the floral coverings are very well developed. They show wonderful differences in form, size, and colour and these have an important bearing on pollination. Certain flowers show special mechanisms for depositing pollen on a definite part of the body of the insect. Observe the flower of the Bean or *Crotalaria*. The large petal on the posterior side known as *Standard* is conspicuous and it attracts the insect. Usually heavy bodied insects like wasps visit these flowers. They find in the boat-shaped body of the corolla, the *keel*, a comfortable seat. The keel encloses the staminal sheath and the style. The mechanism in this flower is such that every time the keel happens to be pressed down, the stamens shoot up. A large quantity of pollen grains is often collected at the tip of the keel and when the stamens shoot up, the pollen grains are deposited on the abdomen of the insect. When the insect visits an older flower, the keel is pressed down and the stigma that comes up touches the abdomen and receives the pollen grain. There is thus in the Bean type the *piston* mechanism for pollination. The insect-visit is always followed by pollination. When pollen is deposited, the way is prepared for fertilisation.

Fertilisation. The pollen grain is a small spherical body with a wall enclosing the living substance. When it is deposited on the stigma, it absorbs the fluid secreted by the stigma and swells. The outer layer of the wall is ruptured at the thin part and the contents with the inner wall protrude in the form of a short tube known as *pollen-tube*. The pollen-tube elongates, forces a passage through the style, and grows towards the ovule inside the ovary. By this time there are formed two male cells in the pollen-tube which is to carry them directly to the egg. The pollen-tube enters the ovule through the micropyle and comes into contact with the embryo-sac. The two sperms find themselves in the embryo-sac and one of them

fuses with the egg. This fusion of the sperm with the egg constitutes fertilisation. The fertilised egg is at once stimulated by this process and it begins to divide and develop into the embryo or the rudimentary plant. The process of fertilisation is significant on account of its stimulating effect. The fertilised egg is first of all stimulated to develop into the embryo. This stimulus extends also to the ovule and the ovule so stimulated becomes altered into the seed. The stimulus extends farther and induces changes in the ovary. The ovary develops along different lines, becomes generally fleshy and

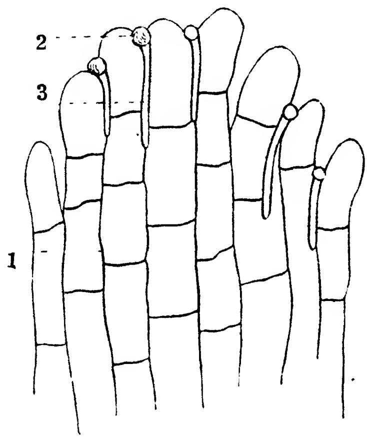


Fig. 179. Pollen grains on the stigma : 1. Stigma with papilla-like projections ; 2. and 3. Pollen germinating and forming a pollen tube.

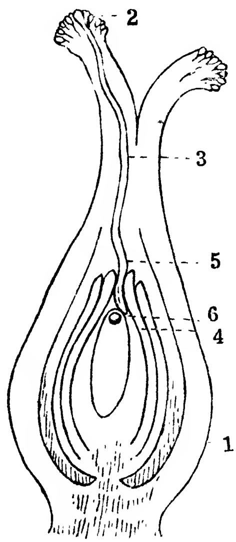


Fig. 179-A. Fertilisation : 1. Ovary ; 2. Pollen on the stigma ; 3. Pollen-tube ; 4. Integuments of the ovule ; 5. Pollen-tube near the micropyle ; 6. Egg in the Embryo-sac.

assumes colours. Such altered ovaries are called *fruits*. The formation of seeds and fruits is impossible if fertilisation does not take place. Fertilisation has thus a direct connection with reproduction. It has also a special significance. It provides an opportunity for the mingling together of the *characteristics*

derived from two different individuals. Thus the descendants may happen to differ in some respects from the ancestral forms and new forms may become established. The life-history of the flowering plant may be illustrated as follows:

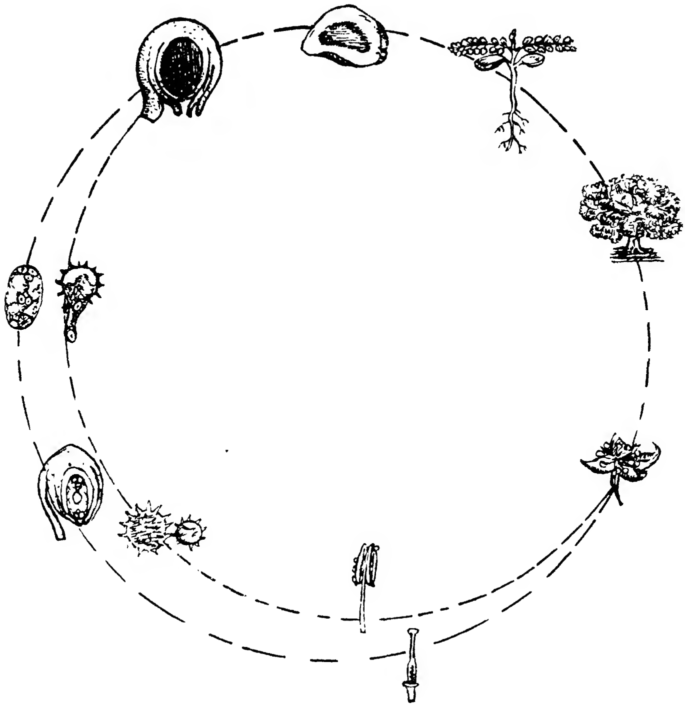


Fig. 180. Life-cycle of the Flowering plant.

SUMMARY

Reproduction may be vegetative or asexual or sexual. In the vegetative and asexual reproduction, only one individual is concerned and a part of the body, say a cutting or a bud, or a spore is detached. In the sexual reproduction two sex-cells derived from two different sources are concerned and the fusion of the two cells has a stimulating effect.

Sexual reproduction may be conjugation or fertilisation.

The Flower is a specialised shoot and many of its features are directly related to pollination.

Pollination is the transport of pollen from the anther and deposition of the same on the stigma. It may be cross-pollination or self-pollination according as the pollen is obtained from another flower or the same flower. In nature there are several devices to prevent self-pollination and to encourage cross-pollination.

Wind and insects play an important part as pollinating agents. Anemophilous flowers are almost naked while entomophilous flowers are usually bright with large perianth.

The pollen that has been deposited on the stigma undergoes changes before sperms are produced and the pollen-tube gets into the ovule with the two sperms at its tip.

The ovule produces the egg in the embryo-sac and one of the sperms taken by the pollen-tube right to the embryo-sac fuses with the egg. Fertilisation has a great stimulating effect and the fertilised egg develops into the embryo while the ovule becomes the seed.

CHAPTER XIX

SYSTEMATIC BOTANY

Classification. Observe carefully the plants that you meet in the field during excursions. Compare the plants which you have studied in the laboratory with one another. You will find a varying degree of resemblance among them. A few may not have much in common with the rest, while many may show a close resemblance among themselves. What is the meaning of this resemblance? If you are asked to arrange the plants you have collected, you will divide them into groups according to their resemblances. Plants which are more or less alike will naturally be put in one group or bundle; and if your collection be large, there may be several bundles. You will proceed to arrange the different bundles into still bigger groups according to their resemblance.

Fig. 181. Linnaeus.
(From Mr. Sinnott's Botany.)

In the former case, the resemblance will be very close and extend even to detailed characteristics; but, in the latter case, the resemblance will be only with regard to general characters. Proceeding in this way, you may succeed in bringing all plants under one main kingdom, the **Vegetable Kingdom**; and all forms that are included in this kingdom will agree generally in the presence of the green pigment. Thus, the wider the group, the more general will be the resemblance. The smaller the group, the closer will be the resemblance. Plants that are classified according to their resemblances will happen to be arranged in groups

subordinate to a group in a telescopic manner. The meaning of this resemblance will be explained later on but it may be stated here that it is a clear indication of blood-relationship among living forms. The aim of classification is to arrange plants according to the degree of relationship. We owe this important idea of affinity or blood-relationship to the great naturalist, Charles Darwin.

Scheme. The following scheme of classification is generally adopted with regard to plants.

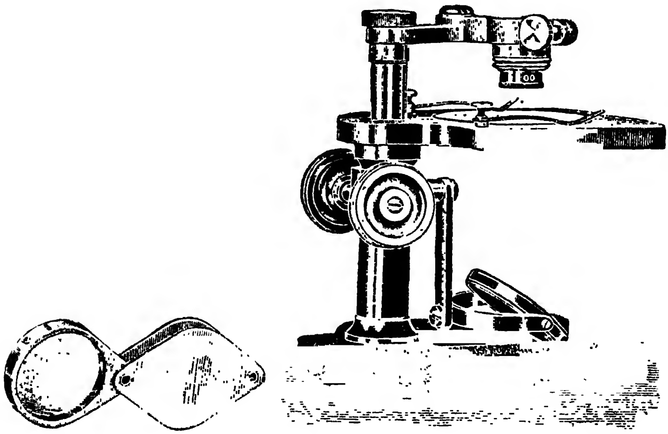
Vegetable Kingdom

- Flowerless plants. (Cryptogams)
- Flowering plants. (Spermatophytes or Phanerogams)
  - Angiosperms. (Ovules inside the ovary)
    - Dicotyledons
      - Family or Natural order (Say Malvaceae or the Cotton group)
        - Genus (Say *Hibiscus*)
          - Species (*Hibiscus esculentus*)
    - Monocotyledons
      - Family or Natural order (Say Palmae or the Palm group)
        - Genus (Say *Cocos*)
          - Species (*Cocos nucifera*)
  - Gymnosperms. (Ovules naked—no ovary e.g. Pines)

Nomenclature. Individual plants which are more or less alike in all respects and which cannot be distinguished from one another constitute one kind or *Species.* Individuals form the unit and the species is the first group or bundle and the closest resemblance is naturally noticed in the members of this group. Different species which resemble one another and

which may therefore be regarded as allied to one another will constitute a bigger group or *Genus*. Thus the genus, *Hibiscus*, comprises a number of allied species, such as *Hibiscus esculentus, Hibiscus rosa-sinensis* and so on. The genus may be regarded as consisting of a number of closely allied species. The allied species of a genus agree in major characters but will be easily distinguished from one another by the size, nature, and form of the leaf and by the colour of the flower and so on. These minute distinguishing features which help us to recognise easily the different species of a genus are known as specific characters. In their turn, the different genera may show a resemblance among themselves and such allied genera form a *Family* or *Natural order* (The term " Natural order " is used by some in a slightly different sense from Family). Thus, *Hibiscus* has much in common with *Gossypium* (the Cotton type) and *Thespesia,* and these genera are brought together under one family, *Malvaceae*, along with other allied genera. The different genera of a family will differ in several important characters and the resemblance will be only of a general nature. In ancient days, the technical names of plants and animals were in the form of a long description ; and the local names that were in use caused a good deal of confusion. A handy and convenient method of naming or *nomenclature* was established by **Linnaeus**, a great Swedish Botanist of eighteenth century. His procedure is known as *Binomial nomenclature* because each species is given a compound name of two words, one being written a little apart from the other, e.g. *Hibiscus esculentus.* The first word is written in the substantive form in capital letter and it forms the name of the genus. The second word is intended to specify the particular species in the genus and is therefore written in the qualifying or adjectival form in small letter. The two words will have to be written when an individual species is under consideration. Classification is, therefore, based on the study of resemblances ; and it will be a natural classification if it is based on a comparative study of the characters of all the organs of plants. A detailed descriptive study of plants is called *Systematic Botany.* Some of the common families of the Angiosperms will now be dealt

with in detail. The chief characteristics which are commonly recognised in plants belonging to each family will be mentioned. It goes without saying that all the characters of the family cannot be seen together in every species. The study of the families of Flowering Plants will be followed by an account of the general structure and life-histories of the more important forms of Flowerless Plants.



1 2

Fig. 181-A. Aids. 1. A Lens ; 2. A Dissecting microscope.

(Summary at the end of Chapter XXI.)

CHAPTER XX

FAMILIES : DICOTYLEDONS

Anonaceae

A family common in South India ; shrubs, and trees.

Leaves. Alternate ; simple ; exstipulate ; bi-farious, i.e., in two rows ; slightly wavy.

Flowers. Not attractive ; odorous in some ; many in axillary clusters, or one or a few opposite to the leaf in which case the growth of the shoot is sympodial ; bisexual.

Calyx (abbreviated form *Cal.*). 3 ; polysepalous ; small.

Corolla (*Cor.*). 3 + 3 ; sometimes only 3 ; polypetalous ; fleshy ; greenish ; valvate ; slightly hollowed at the base so as to protect the essential organs.

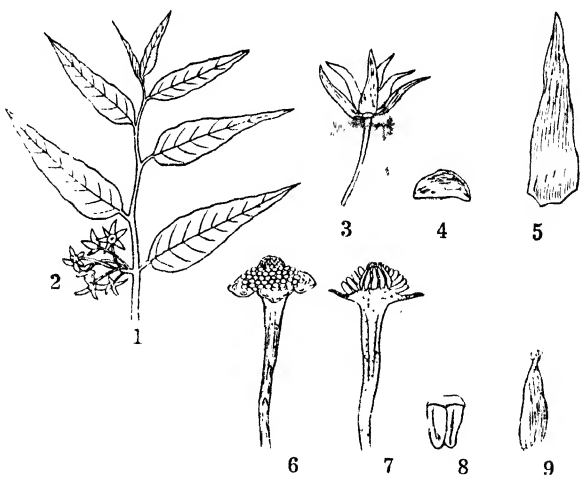


Fig. 182. Polyalthia longifolia ; 1. Shoot ; 2. Flowers ; 3. A flower ; 4. A sepal ; 5. A petal ; 6. Essential organs ; 7. L. S. of the same showing anthers and pistils ; 8. Anther ; 9. A single pistil from the cluster.

Stamens (*Stam.*). Very many; anthers sessile and crowded in a close spiral at the lower part of the bulging

convex thalamus ; bilobed ; connective prolonged beyond the anther lobes into a hood.

Pistil (*Pist.*). Apocarpous, a large number of smaller free pistils crowded together on the top of the bulging part of the thalamus ; pistils free generally but sometimes cohering owing to the fleshy development of the thalamus ; ovary superior, one-celled and one-ovuled ; fruit aggregate, forming a cluster of small independent berries attached by short stalks to the top of the thalamus or a compact oval body with the different

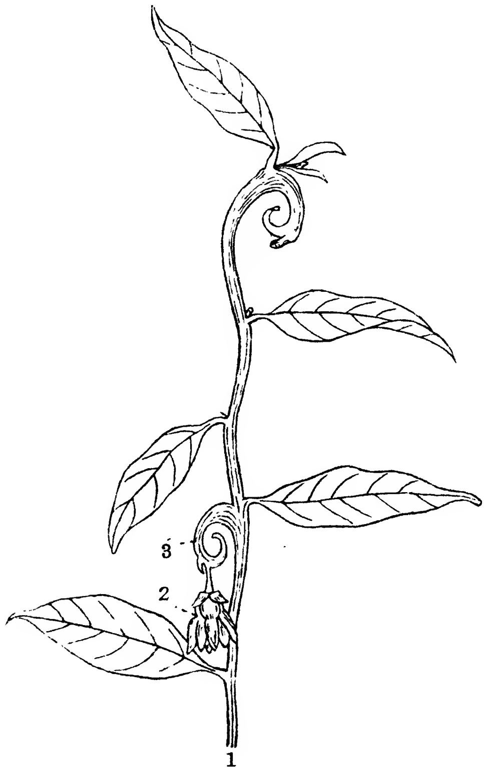


Fig. 183. Artabotrys : 1. Shoot ; 2. Flower ; 3. Hooked peduncle.

ripening ovaries embedded in the fleshy mass into which the thalamus has developed ; seeds albuminous ; endosperm hard and ruminate.

EXAMPLES

1. *Polyalthia longifolia.* A common tree on the road; flowers, many in axillary clusters; petals six; fruit aggregate, with independent berries.

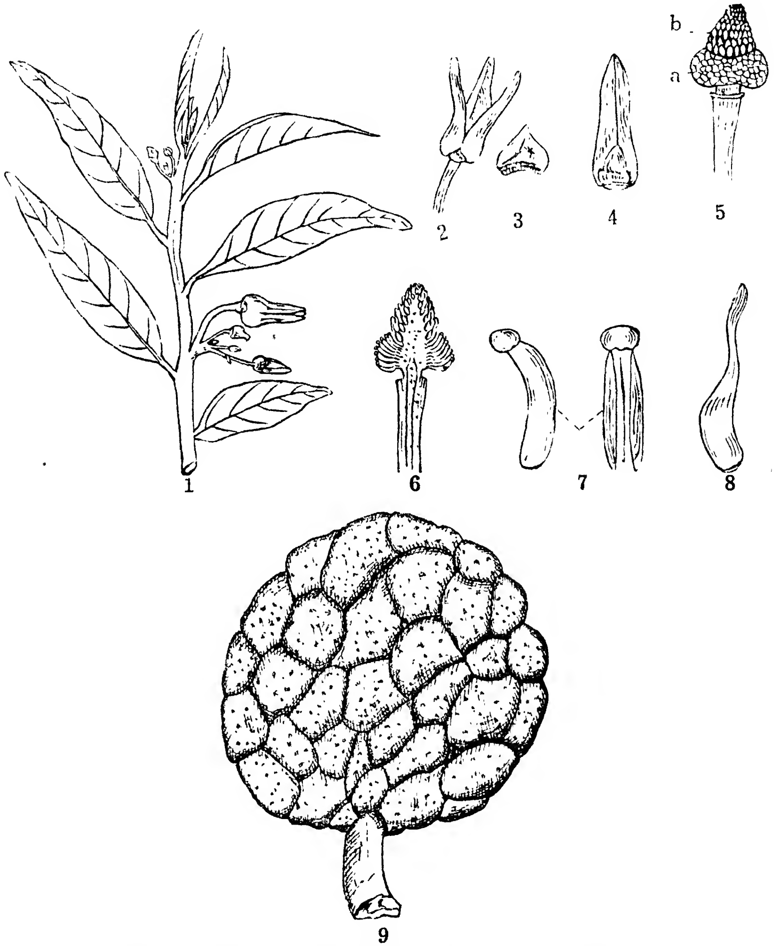


Fig. 184. Anona squamosa : 1. Shoot with flowers ; 2. A flower ; 3. A sepal ; 4. A petal ; 5. Essential organs : (a) Stamens, (b) Clustered pistil ; 6. Upper part of the flower in section ; 7. Anthers in different views ; 8. A single pistil ; 9. Aggregate fruit.

2. *Artabotrys odoratissimus.* A straggler grown in gardens for the odorous flower; flowers, solitary on a hooked

peduncle and opposite to a leaf; growth sympodial; similar to *Polyalthia* in other respects.

3. *Anona squamosa.* A shrub; flowers, a few opposite to the leaf; petals only 3 and fleshy; pistils cohering even at an early stage and the aggregate fruit is compact; fruit edible (Sita fruit).

* * *

Malvaceae

A large family very common in South India; herbs, shrubs and trees; stellate hairs sometimes present on the shoot.

Leaves. Alternate; simple, rarely palmately compound; stipulate; palmate reticulate; usually palmately lobed.

Flowers. Usually solitary, axillary; large and showy; bisexual; pedicel inclined when young and often articulated; bracteoles 3 or more, situated close to the calyx and forming what is known as *Epicalyx;* epicalyx, a common feature in this family.

Cal. Gamosepalous; 5 toothed or lobed; valvate; persistent; inferior.

Cor. Polypetalous; 5; obovate; somewhat plaited; deeply convolute; adhering to the base of the staminal tube; hypogynous.

Sta. Very many; monadelphous, forming a long central tube known as the *Staminal tube,* with a broad base and a long neck; basal part growing with the petals; stamens falling with the corolla; filaments slender, short, and springing from all along the neck or from the top alone; anthers only **one-lobed and opening by one slit**; hypogynous.

Pist. Syncarpous; ovary and style enclosed by the staminal tube; superior; 5-celled but varying from 3 to many; ovules one to many; placentation axile; style 1, sometimes divided into 5 or more branches; stigma one or one for each stylar branch; fruit, either a loculicidal capsule or a schizocarp; seeds with an outgrowth of hairs on the testa in several cases.

EXAMPLES

Gossypium herbaceum (the Cotton plant). Epicalyx of 3 large bracteoles ; the cotton of commerce being the hairy outgrowth on the testa and hence the economic value of the plant ; fruit, loculicidal capsule splitting into 3 valves.

Hibiscus esculentus. A common vegetable ; fruit, loculicidal capsule formed from a 5-celled ovary. Style dividing

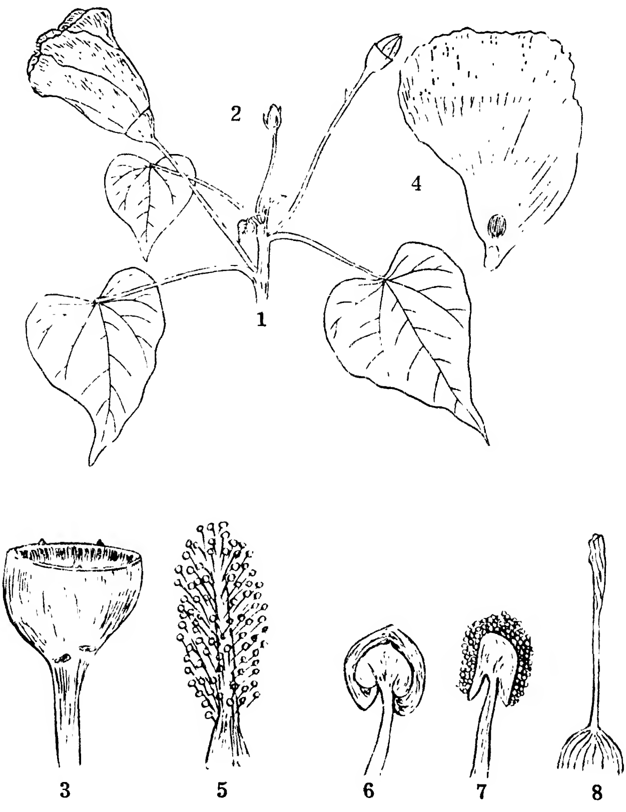


Fig. 185. Thespesia : 1. Shoot with flowers ; 2. A flower bud with bracteoles ; 3. Calyx ; 4. A petal ; 5. Staminal tube with many stamens ; 6. An anther ; 7. The anther opening by a slit ; 8. Pistil.

into 5 branches ; epicalyx of several narrow bracteoles. Some allied species yield good fibres.

Thespesia populnea. A common tree; timber valuable; Epicalyx of 3 deciduous bracteoles; calyx cup-shaped and minutely 5-toothed.

Abutilon indicum. A plant in waste places; fruit a schizocarp formed of a many-celled ovary. Epicalyx absent; style dividing into many branches.

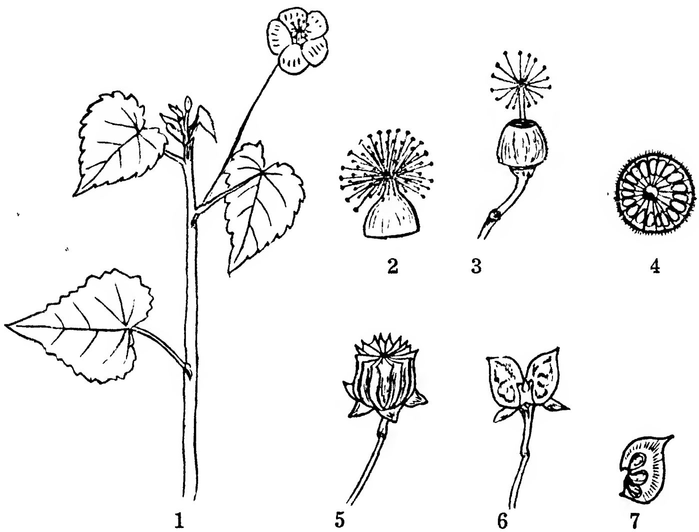


Fig. 186. Abutilon indicum : 1. Shoot with a flower ; 2. Monadelphous stamens ; 3. Pistil with many stylar branches ; 4. C. S. of the ovary ; 5. A ripe fruit ; 6. Schizocarp ; 7. A coccus with a few seeds.

Sida cordifolia. A common weed in open places; fruit schizocarp; coccus with a pair of bristles or awns helping transport by animals.

Bombax malabaricum. A deciduous tree; leaves palmately compound; flowers large with **pentadelphous** stamens; hairy outgrowth on the testa silky. The Red-cotton tree.

Eriodendron. A tall tree with palmately compound leaves; hairs on the testa used for stuffing pillows. The White-cotton tree.

* * *

Rhamnaceae

A small family commonly met with in the scrub-jungle; shrubs or trees; some as scramblers clinging to supports by recurved prickles; surface covered with tomentum in some cases.

Leaves. Alternate; simple; stipulate; **stipules being modified into recurved spines or prickles.**

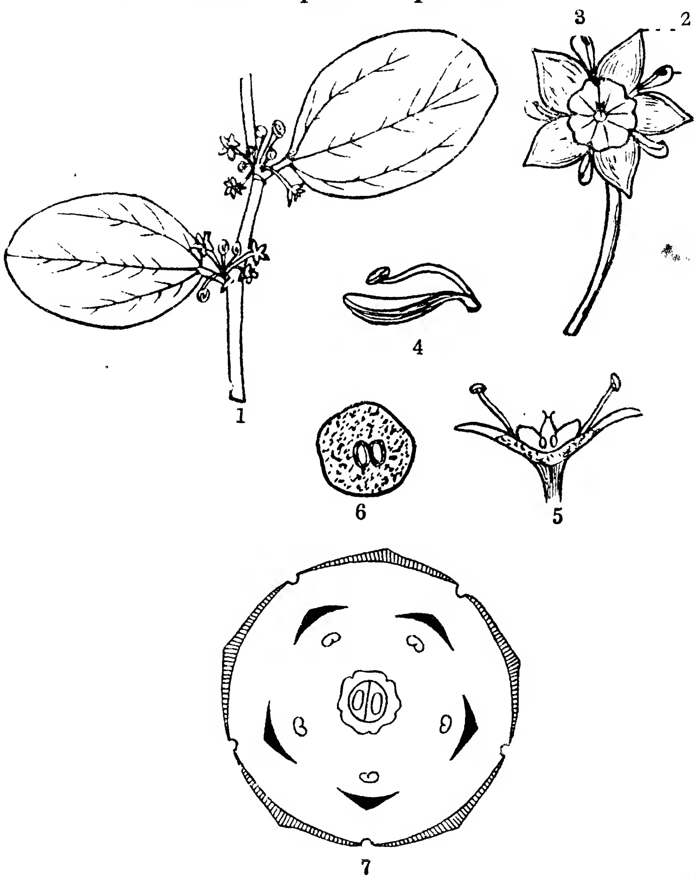


Fig. 187. Zizyphus jujuba; 1. Shoot with fascicles; 2. Sepals; 3. Petals; 4. A stamen in front of the petal; 5. L. S. of the flower; 6. Section of the fruit; 7. Floral diagram.

Flowers. Small; inconspicuous; in small axillary clusters with short pedicels, the clusters being known as

fascicles ; perigynous ; the thalamus cup being filled with a lobed disc.

Cal. Gamosepalous ; 5 ; at the edge of the thalamus cup ; tomentose in some.

Cor. Polypetalous ; 5 ; deciduous ; hooded ; valvate ; at the edge of the thalamus cup ; perigynous.

Sta. Polyandrous ; 5 ; at the edge of the thalamus cup ; perigynous ; **always standing opposite to the petals and enclosed by the petals ; this feature peculiar to this family being described as the antipetalous condition** ; anthers bilobed.

Pist. Syncarpous ; ovary immersed in the disk and invisible at first ; hence described as half-inferior ; style short ; stigma bifid ; ovary becoming visible in the fruit stage : fruit, a drupe or a dry and winged form.

EXAMPLES

Zizyphus jujuba. A shrub or a small tree ; young parts tomentose ; stipules transformed into recurved prickles ; lower surface of the leaf tomentose and whitish and upper surface shining green ; fruit fleshy, an edible drupe.

Ventilago maderaspatana. A common straggler ; fruit, dry with the style enlarged into a narrow erect wing.

* * *

Leguminosae

A large family widely distributed ; herbs, shrubs and trees ; several being twiners ; the name of the family based on the prevalence of the legume type of fruit in this family ; in a few cases, the dry fruit being articulated or jointed at intervals and looking like a string of beads ; such a fruit giving way when ripe at each joint transversely known as *lomentum.*

Leaves. Alternate ; stipulate ; simple or more often compound or bi-compound ; pulvinate.

Flowers. The structure of the flower varies a good deal among the plants included in this family and on the basis of

the floral structure, this big family is divided into three sub-families, each sub-family showing its own type of floral structure. All forms agree in the structure of the pistil which is monocarpous with an one-celled flat ovary and marginal placentation.

The three sub-families are (*a*) Papilionaceae, (*b*) Caesalpinieae, and (*c*) Mimoseae.

(a) Papilionaceae (Papilionatae)

A large sub-family of herbs, shrubs and trees ; several as twiners.

Leaves. Alternate ; stipulate ; pulvinate ; simple in some ; very often compound ; usually trifoliately compound (with three leaflets in each leaf).

Flowers. In terminal and axillary racemes ; bi-sexual ; irregular since the petals are not similar in size and form ; perigynous.

Cal. Gamosepalous ; 5 toothed.

Cor. Polypetalous ; 5 ; differentiated into a large posterior, stalked, circular petal, called *standard,* a pair of small stalked oblong petals, one on each side, known as *wing petals,* and an anterior boat-shaped body, called *keel* formed by the cohering of the two petals on the anterior side ; such a type of corolla being termed **papilionaceous** ; descendingly imbricate ; the standard overlapping in the bud-stage and the opening of the flower proceeding from above downwards ; wing-petals in close contact with the keel.

Sta. 10, monadelphous ; or in several cases diadelphous, of 9 and 1, the solitary free stamen always standing in front of the standard ; the united portion of the stamens appearing as a folded sheath.

Pist. Monocarpous, ovary one-celled ; a few to many ovules ; placentation marginal ; style long ; fruit a legume.

ovary is brought into contact with the soil and the fruit ripens in the soil (Fig. 228).

Pisum sativum (Pea plant). Stipules foliaceous; upper leaflets transformed into tendrils; seeds edible.

Sesbania grandiflora. A slender plant cultivated for the edible leaves. Flowers very large.

Phaseolus (Pulses). Seeds highly valued as food-stuff.

Indigofera tinctoria. Herbs; once largely cultivated for the sake of the indigo dye.

(b) Caesalpinieae (Caesalpinioideae)

A large sub-family of herbs, shrubs and trees.

Leaves. Alternate; stipulate; pulvinate; compound or bipinnately compound.

Flowers. In terminal and axillary racemes; slightly irregular; bisexual; perigynous.

Cal. 5; polysepalous, sometimes petaloid; inferior.

Cor. 5; polypetalous; stalked; posterior petal, smaller completely overlapped, and useful as a nectary; ascendingly imbricate; perigynous; irregular.

Sta. 10; polyandrous; staminodes in some; anthers sometimes opening by pores; filaments fairly long; perigynous.

Pist. Monocarpous; ovary superior, one-celled and many-ovuled; placentation marginal; style long; fruit, a legume.

EXAMPLES

Caesalpinia pulcherrima. An ornamental shrub; leaves bipinnately compound.

Cassia auriculata. A small shrub common in the scrub jungle; stipules foliaceous; leaves pari-pinnately compound; the bark of the species of Cassia useful as tanning material; some stamens as staminodes and anthers opening by pore.

Fig. 192. Pithecolobium dulce : 1. Shoot ; 2. A flower ; 3. Pistil ; 4. Fruit ; 5. A Seed with white aril.

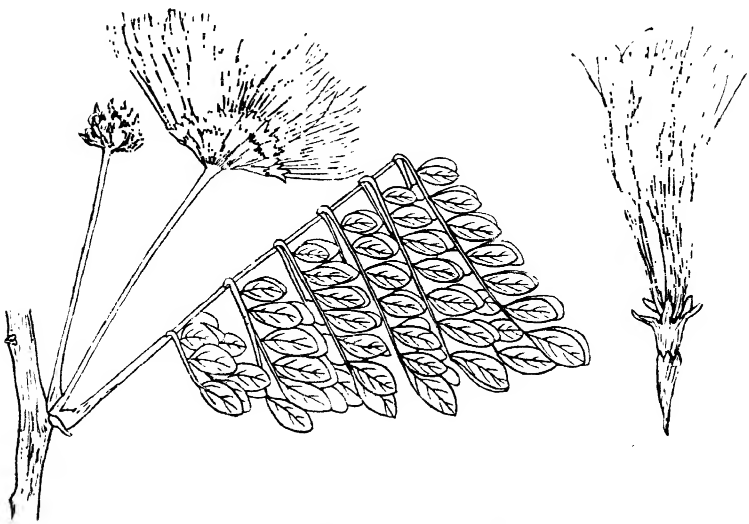


Fig. 193. Enterolobium saman : The Rain tree.

Enterolobium saman (the Rain tree). A common avenue tree; stamens finely coloured.

Mimosa pudica (the Sensitive plant). A herb with emergences; leaves **digitate pinnate.** Flowers in small coloured heads.

Adenanthera pavonia. A big tree; flowers in panicles; seeds coloured.

* * *

Myrtaceae

A large family of shrubs and trees; bark scaly, and the surface of the stem often greyish.

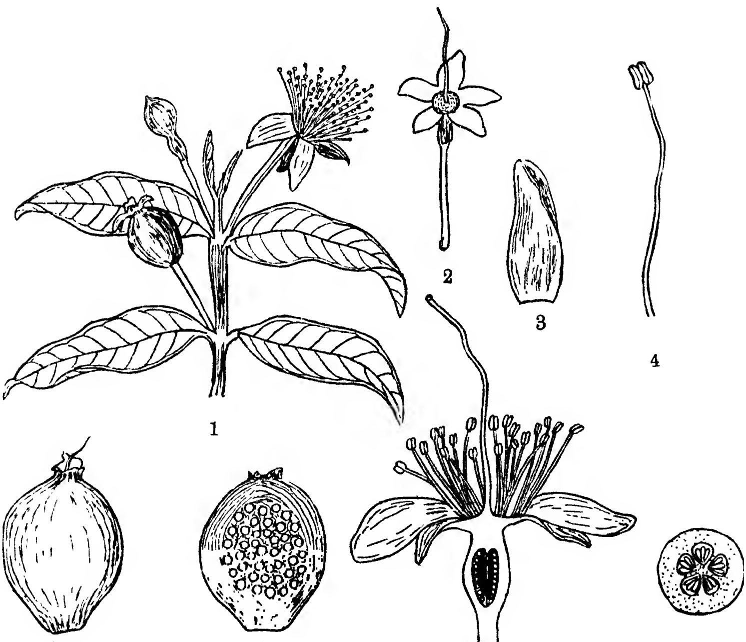


Fig. 194. Psidium: 1. Shoot; 2. Pistil with superior calyx; 3. A petal; 4. A stamen; 5. L. S. of the flower; 6. and 7. Fruit; 8. C. S. of the ovary.

Leaves. Simple; usually opposite; rarely alternate and crowded at the ends of branches; leathery; aromatic and gland-dotted (leaves, when held up to light and observed,

showing small glandular receptacles as dots in the tissue), with a special vein called *intra-marginal* vein running inside the margin and closely parallel to it.

Flowers. Not attractive; solitary and axillary or in cymose panicles; epigynous. (The Cloves sold in the bazaar are the dried flower buds of a plant of this family).

Cal. 5; gamosepalous; *superior,* persistent on the fruit.

Cor. 5; polypetalous; deciduous and usually falling off together; white; imbricate; epigynous.

Sta. Many; polyandrous; filaments fine and bent inwards (crumpled) in the bud; sometimes coloured.

Pist. Syncarpous; ovary *inferior;* cells varying from 2 to many; ovules one to many; fruit, a berry; rarely a capsule; seeds with hard testa.

EXAMPLES

Psidium guava. A common tree cultivated for the edible berries; many-seeded; calyx persisting on the berry.

Fig. 195. Syzygium: 1. Shoot with cymose panicle; 2. A flower; 3. A bud; 4. L. S. of the flower; 5. A fruit.

Syzygium jambolanum. A common tree. Flowers in cymose panicles. Fruit one-celled and one-seeded berry; timber valuable.

Eucalyptus (Blue-gum). A tree introduced from Australia and growing well in the Nilgiris; eucalyptus oil obtained from the leaves; young leaves bluish and varnished; lower leaves opposite and large; and upper leaves narrow and alternate.

* * *

Convolvulaceae

A large family of twiners; a favourite in the gardens owing to their rapid growth; a white fluid or latex exuding when the leaf is plucked or stem injured.

Leaves. Alternate; simple; exstipulate; cordate; sometimes hastate; often palmately lobed.

Flowers. Large and showy; bi-sexual; solitary axillary or in axillary cymose clusters.

Cal. 5; polysepalous; imbricate; slightly unequal.

Cor. Gamopetalous; 5 toothed or lobed; funnel-shaped; plaited; 5 radiating lines or bands on the corolla; twisted.

Sta. 5; epipetalous; filaments slightly unequal; anthers bilobed.

Pist. Syncarpous; ovary superior; 2-celled with two ovules in each cell or 4-celled with one ovule in each cell; surrounded at the base by a cup-shaped nectary or disc. Style single; stigma bifid, big and globose generally; fruit, a septifragal capsule.

EXAMPLES

Ipomaea (Fig. 196). A common genus with several forms grown in gardens; stigma bifid and globose always. *Ipomaea pes-caprae,* a creeper on the beach. *Ipomaea batatas,* a creeper largely cultivated for the edible root tubers known as *sweet potato.*

Evolvulus alsinoides. A small prostrate plant; flowers solitary axillary.

Cuscuta (the Dodder). A peculiar twining plant leading a completely parasitic life; leaves reduced to very minute scales and the stem yellow.

Acanthaceae

A common family ; herbs and a few shrubs ; stem square and swollen at the nodes.

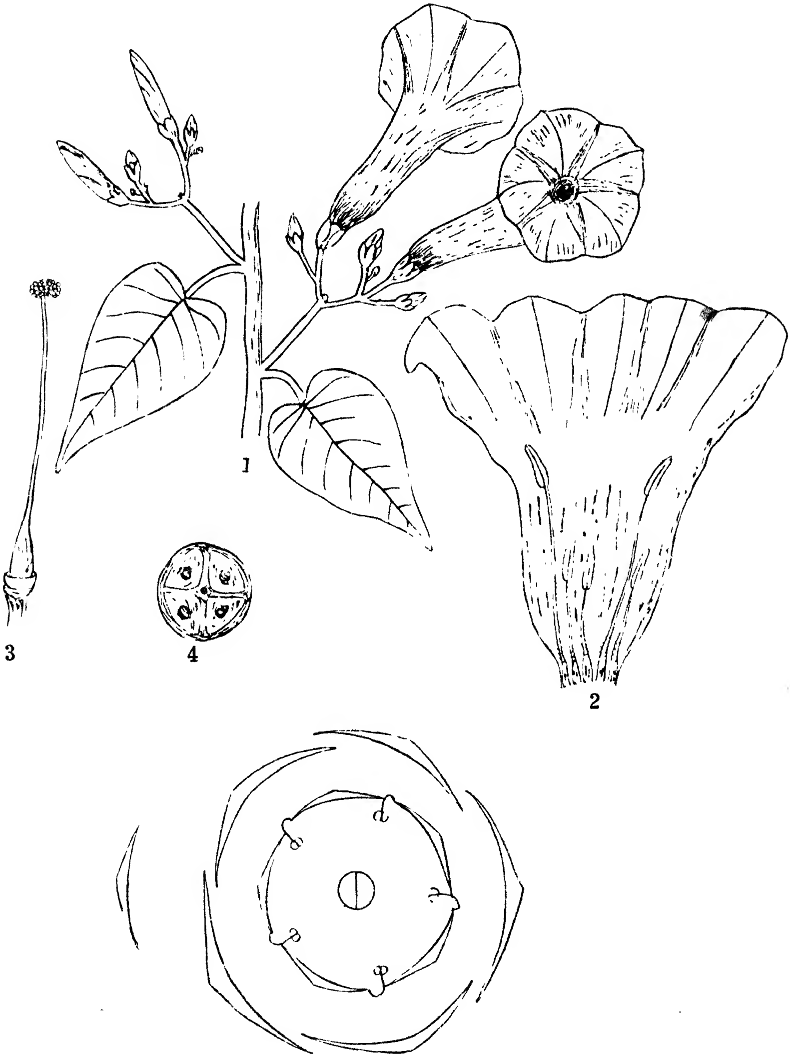


Fig. 196. Ipomaea carnea : 1. Shoot with flowers ; 2. Corolla spread out ; 3. Pistil ; 4. C. S. of the ovary ; 5. Floral diagram.

Leaves. Opposite ; decussate ; exstipulate.

Flowers. Often in spikes with fairly large leafy bracts ; bracteolate ; irregular ; bisexual.

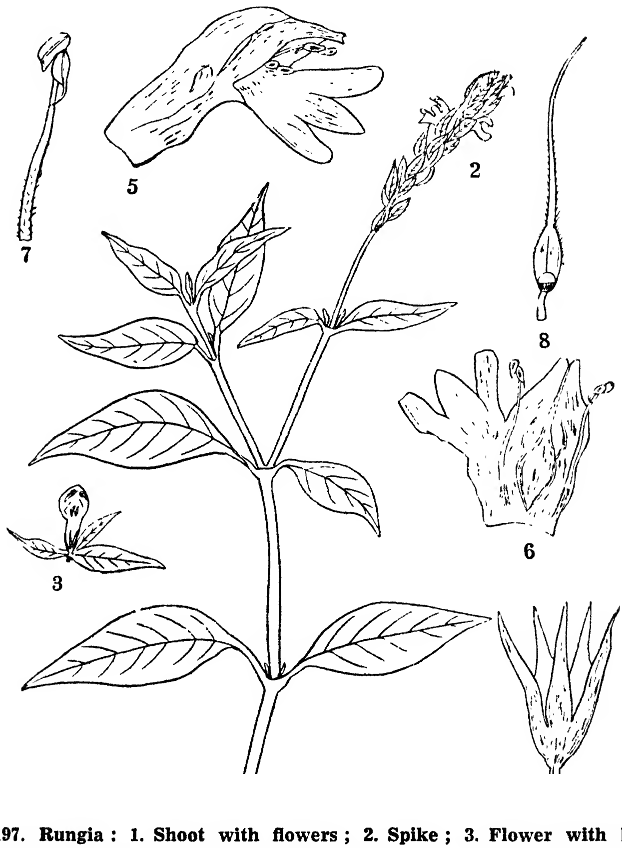


Fig. 197. Rungia : 1. Shoot with flowers ; 2. Spike ; 3. Flower with bract and bracteoles ; 4. Calyx ; 5. Labiate corolla ; 6. Corolla spread out ; 7. A Stamen ; 8. Pistil.

Cal. 5 ; almost polysepalous ; long and narrow ; persistent.

Cor. 5 ; gamopetalous ; usually bi-labiate ; upper lip with two lobes and the lower lip with three lobes ; imbricate or twisted ; lobes unequal.

Stam. 4 *didynamous* (arranged in two pairs, one pair with longer filaments and the other pair with shorter filaments); the stamen on the posterior side being suppressed;

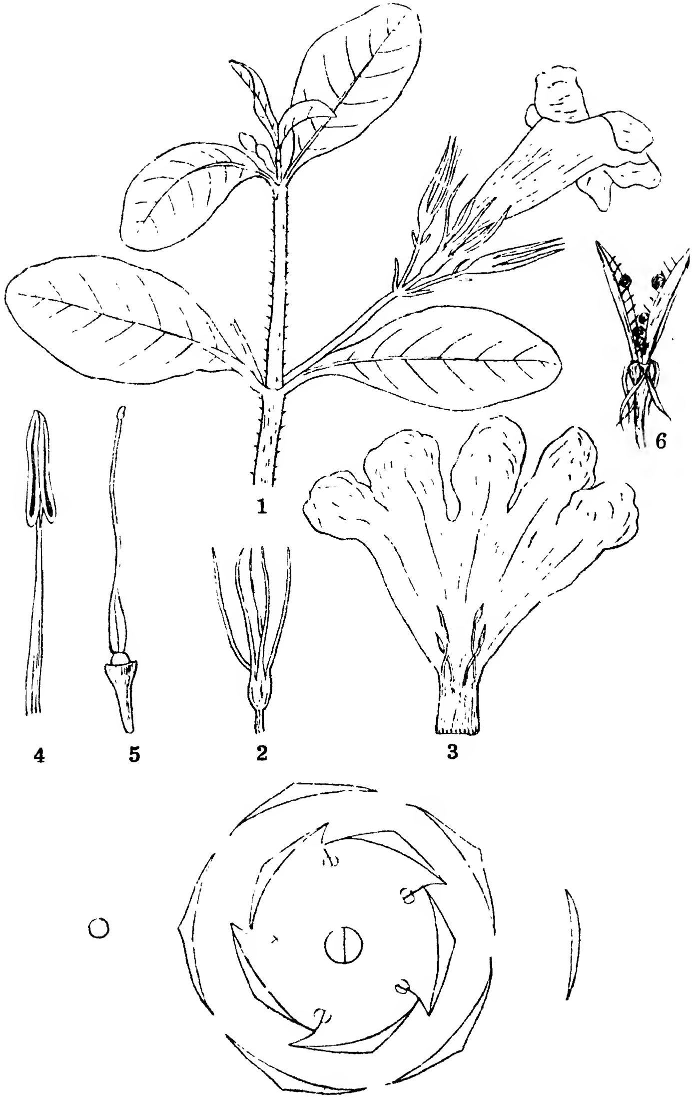


Fig. 198. Ruellia : 1. Shoot with flowers ; 2. Calyx ; 3. Corolla spread out ; 4. A stamen ; 5. The Pistil ; 6. Explosive fruit ; 7. Floral diagram.

only 2 in some ; epipetalous ; anther lobes 2, one placed a little below the other in some.

Pist. Syncarpous, ovary superior, long, often flattened ; two-celled ; a few to **many flat ovules** in each cell attached to stiff funicles ; style single ; stigma bifid and membranous in some ; fruit, **a loculicidal capsule, explosive in some ; funicles hard and hooked in the fruit and known as retinacula.**

EXAMPLES

Ruellia tuberosa. A common weed ; flowers in axillary cymes ; corolla not clearly labiate ; lobes equal ; stamens 4.

Adhatoda vasica. A shrub useful as a hedge plant ; spikes prominent ; corolla bilabiate ; stamens 2 ; medicinal value.

Justicia prostrata. A common weed ; spikes with bracts and bracteoles ; corolla labiate ; upper lip being very small ; stamens 2.

Rungia. Spikes fairly large ; bracts leafy ; corolla bilabiate ; and stamens 2.

Asteracantha longifolia. A herb with stout thorns ; common near paddy fields. Flowers crowded in the axils of leaves.

* * *

Labiatae

A large family, common in dry places, with strong odour owing to the volatile oil secreted by numerous hairs on the shoot. Stem square ; nodes not swollen.

Leaves. Simple ; opposite ; decussate.

Flowers. Small, very often in special dense clusters in the axils of leaves ; the two clusters found in the axils of the opposite leaves surrounding the stem and looking like a whorl ; the entire whorl being known as *Verticillaster* which is really a congested branched cyme ; sometimes in open thyrsus ; flowers irregular.

Cal. Gamosepalous ; 5 toothed ; sometimes labiate ; persistent.

Cor. Gamopetalous ; 5 ; lobes varying in number ; always bi-labiate ; upper lip with one or two lobes and the lower lip with three lobes ; lobes flat or sometimes hooded or boat-shaped.

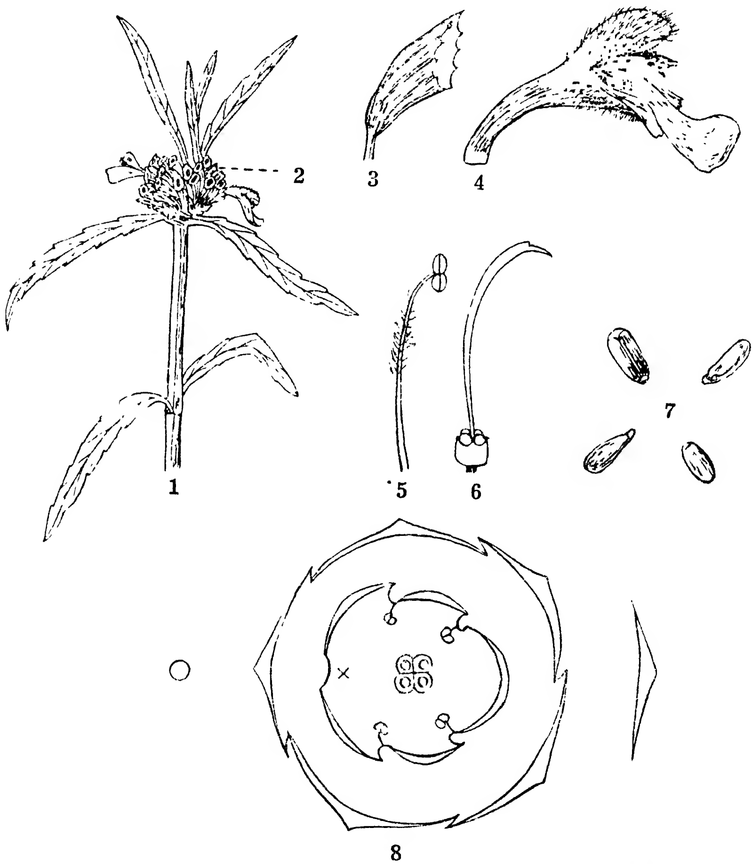


Fig. 199. Leucas aspera : 1. Shoot ; 2. Verticillaster ; 3. Calyx ; 4. Corolla ; 5. Stamen ; 6. Pistil ; 7. Nutlets ; 8. Floral diagram.

Stam. 4 didynamous ; posterior, odd stamen suppressed : or 2 ; epipetalous ; anther bilobed ; the two lobes not parallel to each other but diverging.

Pistil. Syncarpous; ovary superior, deeply cut into four lobes with one ovule in each lobe; style single, proceeding from near the basal region of the lobes of the ovary and passing between the lobes and hence described as *gynobasic;* stigma bifid; a cup-shaped disc surrounding the ovary at the base; fruit in the form of four small separate nutlets.

EXAMPLES

Leucas aspera. A common weed in open dry places; strong odour; verticillasters well-developed; upper lip of the corolla with one hairy hooded lobe; stamens 4.

Fig. 200. Ocimum : 1. Shoot with thyrsus ; 2 Clusters of flowers ; 3. A flower 4. Calyx ; 5. Corolla ; 6. Corolla spread out ; 7. Pistil ; 8. Four nutlets.

Ocimum sanctum (Tulasi). A scented herb; flowers in thyrsus; corolla lobes flat; calyx bi-labiate.

Mentha (Podina). A common herb easily propagated by cuttings and yielding menthol.

There are several points of agreement between Acanthaceae and Labiatae and it may be inferred that the two families are closely related. The gamopetalous bi-labiate corolla, the didynamous stamens, the bicarpellate pistil, the square stem, and the opposite arrangement of leaves are recognised in both families. The bi-labiate corolla should not be considered as always indicating Labiatae. The divided nature of the ovary with the definite number of ovules is peculiar to Labiatae and one can easily distinguish this from Acanthaceae where the ovary is not divided and the ovules are many and flat.

* * *

Rubiaceae

A large family of herbs, shrubs and trees.

Leaves. Simple; opposite or sometimes whorled: stipulate; stipules inter-petiolar; inter-petiolar stipule green, or membranous, with or without bristly endings.

Flowers. Regular, bisexual, in cymose clusters: epigynous.

Cal. 4 or 5; gamosepalous; superior.

Cor. Gamopetalous; 4 or 5 lobed; salver-shaped or rotate; valvate, convolute, or imbricate.

Sta. 4 or 5; epipetalous; anthers bilobed.

Pist. Syncarpous; ovary inferior, 2-celled; style single; stigma bifid in some; one or a few ovules in each cell: fruit, a drupe, or capsule, or berry.

EXAMPLES

Ixora coccinea. An ornamental shrub; inter-petiolar stipule small and greenish; flowers tetramerous (parts in 4) and in cymose clusters; corolla twisted; berry.

Morinda tinctoria. A common tree producing a dye; stipule large and green; flowers in heads; calyx much reduced; fruit, a collective fruit of drupes.

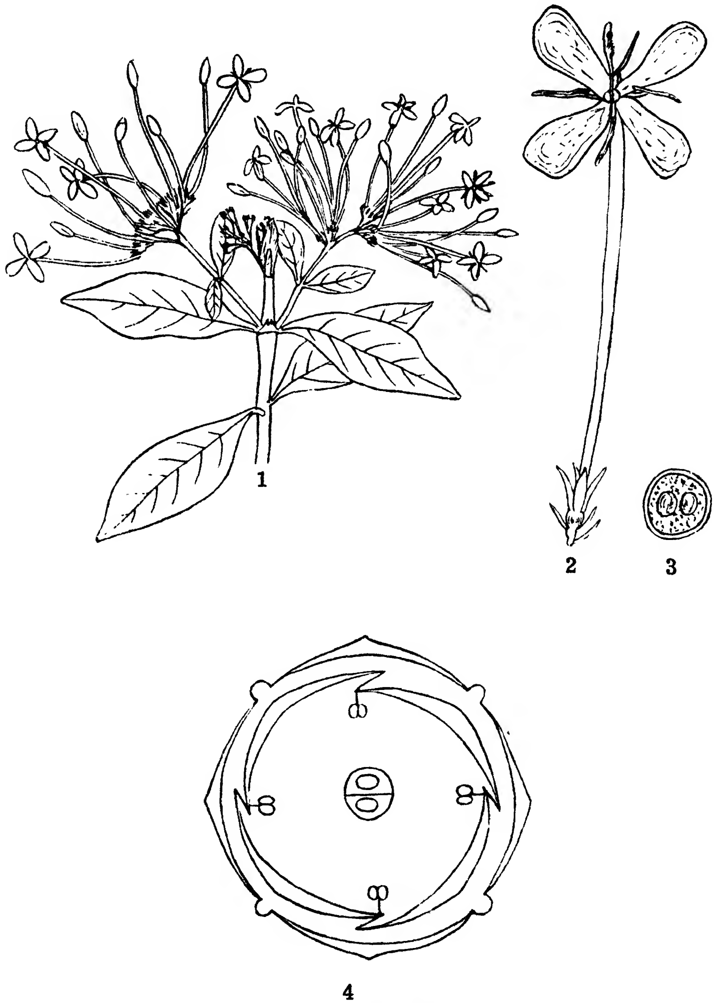


Fig. 201. Ixora coccinea : 1. Shoot with cymose cluster ; 2. An epigynous flower ; 3. C. S. of the ovary ; 4. Floral diagram.

Coffea arabica. A shrub largely cultivated in the hills for the coffee seeds. Fruit fleshy.

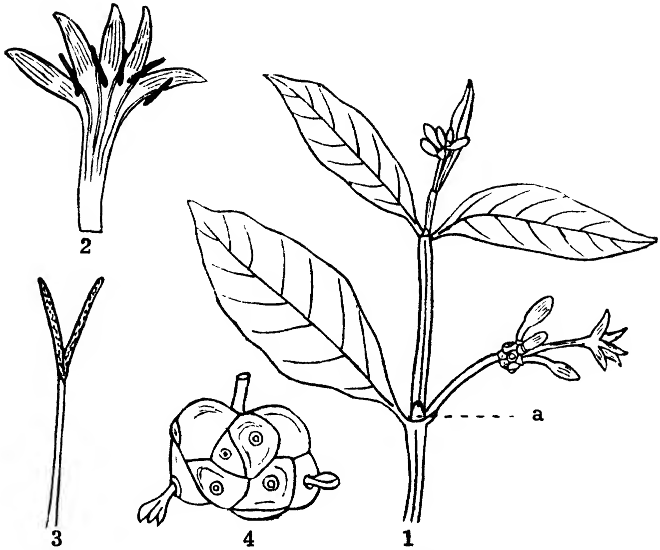


Fig. 202. Morinda : 1. Shoot with a head : a. Interpetiolar stipule ; 2. Corolla and stamens ; 3. Style and bifid stigma ; 4. Collective fruit.

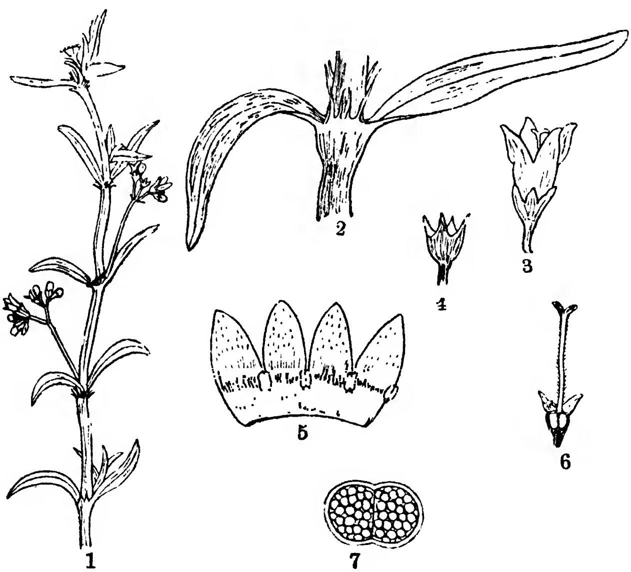


Fig. 203. Oldenlandia : 1. Shoot with flowers ; 2. Leaves with interpetiolar stipules ; 3. A flower ; 4. Inferior ovary with calyx on the top ; 5. Corolla spread out ; 6. The Pistil ; 7. C. S. of the ovary.

Oldenlandia umbellata. A common weed; stipule membranous and bristly; corolla valvate; fruit a capsule.

Borreria hispida. A prostrate herb; stipule with bristly endings; flowers, a few clustered in the axil; fruit a capsule.

Hydrophylax maritima. A creeper common on the sandy beach; leaves succulent.

Cinchona. Cultivated; bark yielding quinine.

* * *

Compositae

A large family, mostly herbs.

Leaves. Simple, alternate or opposite.

Flowers. Small and sessile, always clustered in heads; heads either solitary terminal or many in number and arranged in panicles or umbels; receptacle well developed into a spherical or flat body; involucral bracts many at the base of the receptacle and protecting the small flowers on the receptacle; flowers small and known as florets and generally of two kinds; one kind being a bigger attractive type of floret found towards the outside and known as **ligulate** or **ray floret** and the other kind being of an inconspicuous smaller type called, the tubular floret; the tubular floret forming the typical flower of the family and the ligulate floret being only a modified form.

Tubular floret.

Cal. Not of the normal form; **modified into a tuft of fine hairs or bristles called pappus**; persistent; superior.

Cor. Gamopetalous; 5 toothed; tubular; small; valvate; regular; inconspicuous; epigynous.

Sta. 5; epipetalous; filaments free; **anthers always cohering by their adjoining edges to form a tube so as to leave a canal for the style; united condition of anthers being termed Syngenesious.**

Pist. Syncarpous; ovary *inferior*, always *one-celled* and *one-ovuled;* placentation basal; style single passing through

the anther canal and dividing at the top beyond the anther into two recurved stigmatic branches; the inner part of the stigmatic branch receptive; fruit a small achene, **transported**

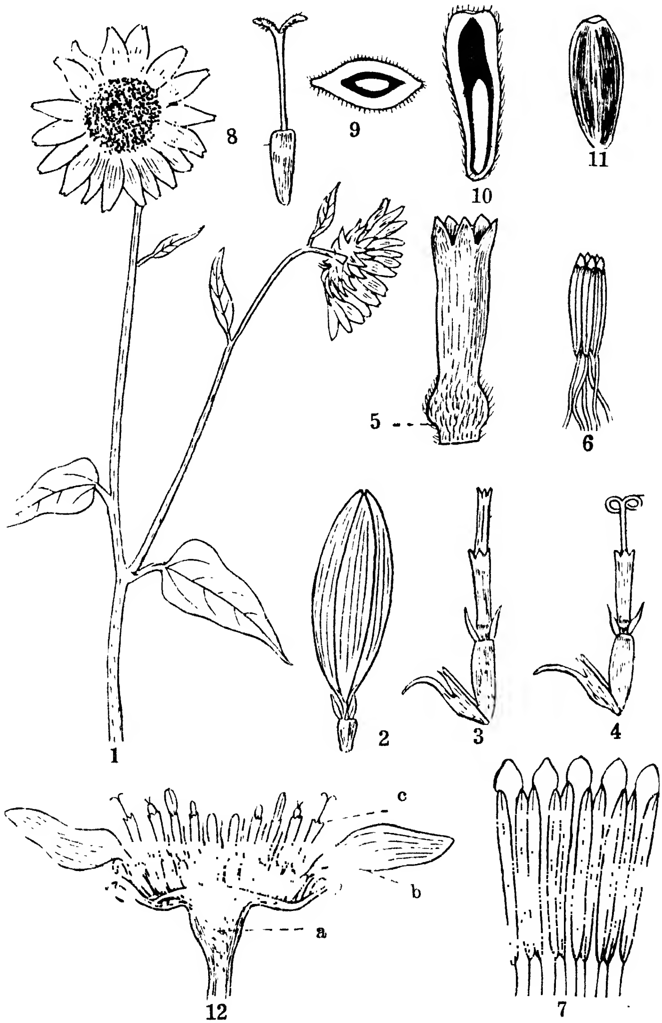


Fig. 204. The sunflower : 1. A Shoot with heads ; 2. Ligulate floret ; 3. and 4. Tubular florets ; 5. Tubular corolla ; 6. Stamens with syngenesious anthers, 7. Anthers spread out ; 8. Pistil ; 9. C. S. of the ovary ; 10. L. S. of the ovary with basal ovule ; 11. Achene ; 12. L. S. of the head ; a. Receptacle, b. Ligulate floret, c. Tubular floret.

easily by wind and sometimes by animals when the pappus consists of bristles.

Ligulate floret.

Cal. As in the Tubular floret.

Cor. **Flat or strap-shaped,** three or more toothed ; corolla becoming flat through the suppression of one-half, namely, the posterior side, or sometimes through the splitting of the corolla rudiment in which case the corolla may appear spread out with more than 3 teeth ; such flat corollas being described as *ligulate.*

Fig. 205. Vernonia : 1. Shoot ; 2. A single head ; 3. A tubular floret ; 4. Achene.

Sta. Absent usually ; 5, if present.

Pist. Same as in the tubular floret but not functioning in certain cases.

The heads of compositae may be of three types.

(1) Plants where the ligulate and tubular florets occur together on the same head as in *Helianthus* (Sunflower).

Head very conspicuous due to the prominent flat corolla of the sterile, pistillate ligulate florets.

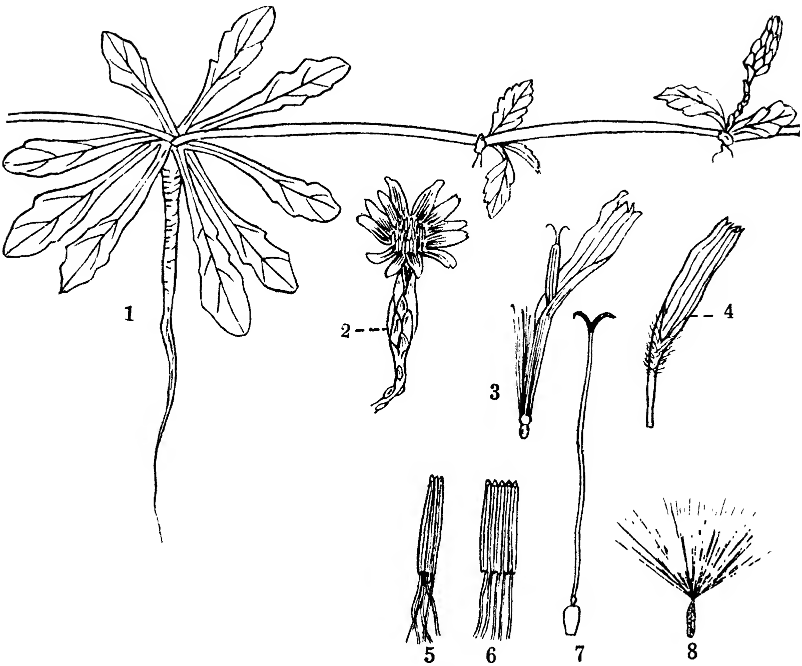


Fig. 206. Launaea : 1. A plant with runner ; 2. A head showing involucre and flowers ; 3. A single bisexual ligulate floret ; 4. Ligulate corolla ; 5. and 6. Stamens with syngenesious anthers ; 7. Pistil ; 8. Achene with persistent pappus.

(2) Plants where the flowers on the head are all of one kind, namely, of the tubular type as in *Vernonia.* Heads not conspicuous.

(3) Plants where the flowers are all of one kind, namely, of the ligulate type as in *Launaea,* common on the sandy beach. Here the head is somewhat conspicuous and the ligulate florets are **bisexual and fertile.** There are 5 stamens with syngenesious anthers.

The first group is the commonest group and it is interesting since it shows a division of labour. One set of flowers, the ligulate florets, is large and attractive at the expense of

the reproductive organs and makes the head conspicuous. The tubular florets are concerned with seed formation.

EXAMPLES.

Helianthus. Large herbs grown in gardens; head very large; involucral bracts in many series; pappus almost absent; flowers of two kinds.

Tridax procumbens. A common weed with two kinds of flowers on the solitary terminal head; pappus hairs many.

Chrysanthemum. Commonly grown for the large heads.

Zinnia elegans. A herb grown in gardens with ligulate and tubular florets.

Vernonia cinerea. A common weed; flowers all tubular; pappus hairy.

Launaea pinnatifida. A plant with runners on the sandy beach; secretion of latex; pappus hairs silky.

* * *

Euphorbiaceae

A large family of herbs, shrubs and trees; secretion of latex a common feature; internodes of the stem in herbs being hollow in several cases.

Leaves. Simple; alternate or opposite; stipulate in most cases; stipules being scaly or modified into small thorns.

Flowers. Usually small and inconspicuous; always **diclinous** or **unisexual** and hence described as **imperfect**; monoecious in most cases and in a few plants dioecious; **incomplete**, i.e., with only one whorl of perianth, the corolla being generally absent; flowers in cymose clusters or in a compact specialised type known as *Cyathium* in one genus.

Male.

Cal. 4 or 5; polysepalous.

Cor. Absent; if present, 4 or 5 polypetalous.

Sta. 4 or 6, or 8, or many; usually monadelphous; sometimes polyandrous; anthers often grouped together; anther lobes diverging; glands surrounding the base of the stamens in some cases.

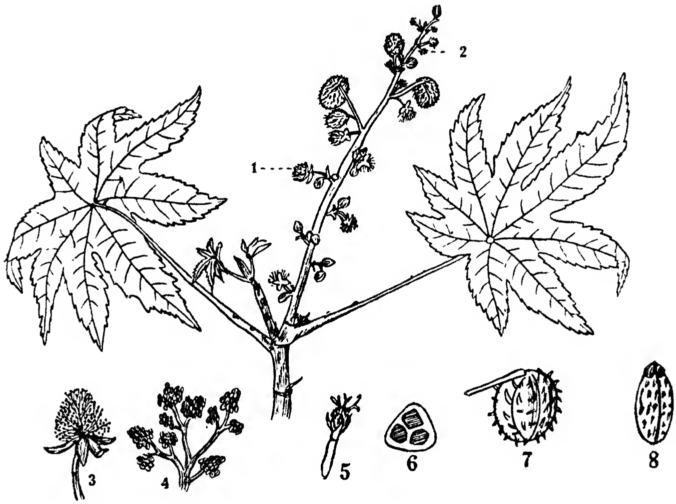


Fig. 207. Ricinus communis: 1. Cluster of staminate flowers; 2. Cluster of pistillate flowers; 3. A staminate flower; 4. A single bundle of stamens branching; 5. A pistillate flower; 6. C. S. of the ovary; 7. A young fruit; 8. A seed.

Female.

Cal. Same as in the male, segments somewhat larger.

Cor. Same as in the male.

Pist. Syncarpous; ovary superior; spherical; three grooved and 3-celled; one or two pendulous ovules in each cell; styles three, persistent, each dividing into a bifid stigma; fruit a schizocarp or drupe.

Ricinus communis. A plant largely cultivated for the oil of the seeds; leaves palmately lobed; flowers monoecious; in a large number of small clusters on a long axis; lower clusters male; upper clusters female; stamens polyadelphous; ovary beset with bristles; perianth of one whorl.

Jatropha gossypifolia. A sticky shrub commonly grown as a hedge plant ; corolla present and attractive ; stamens monadelphous ; schizocarp.

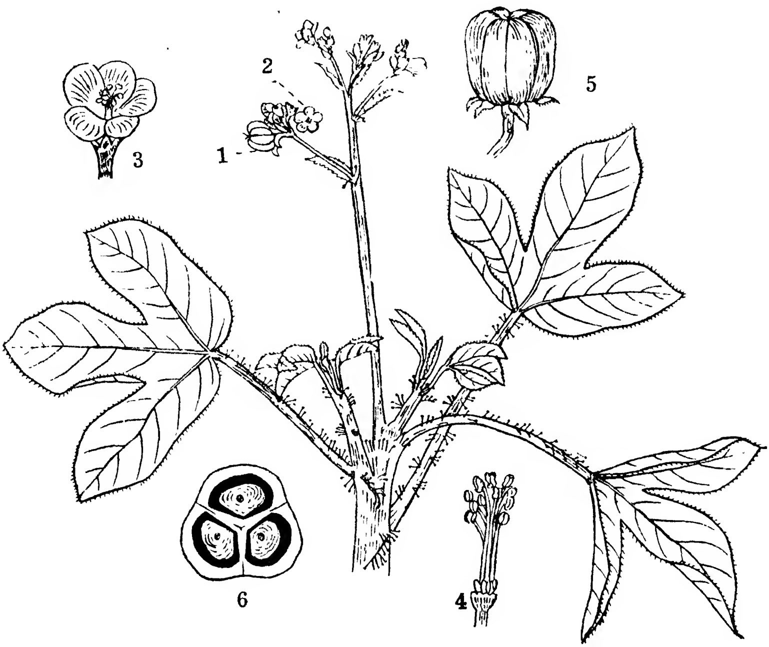


Fig. 208. Jatropha gossypifolia : 1. Pistillate flower ; 2. Staminate flower ; 3. Same as 2 ; 4. Stamens in one bundle ; 5. Ovary ripening ; 6. C. S. of 5.

Croton. Several kinds grown in gardens ; corolla present ; stamens polyandrous. C. sparsiflorus is a recently introduced weed spreading rapidly.

Phyllanthus emblica. A tree with drupaceous fruits useful for pickles.

Phyllanthus niruri. A common herb ; milky juice ; leaves on the main shoot reduced to minute scales and the leafy shoots developing in their axil mistaken for a compound leaf.

Euphorbia. A very common genus consisting of herbaceous or shrubby forms. The shrubby forms are most of them leafless and the stem in certain forms becomes angular with

flat sides, thick and green; stipules transformed into thorns; latex copious; flowers unisexual, small and naked. The two kinds of unisexual flowers are clustered together in a special-

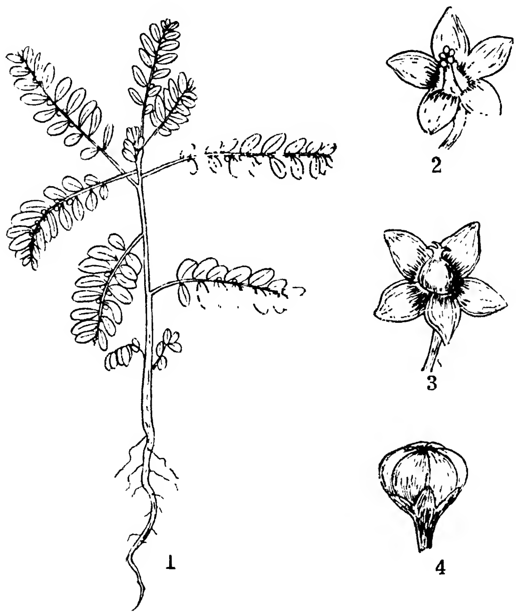


Fig. 209. Phyllanthus niruri : 1. Shoot ; 2. Staminate flower ; 3. Pistillate flower ; 4. Fruit.

ised type or cluster called *cyathium*. The receptacle (called involucre in this case) is a hollow body which produces one naked female flower on a long pedicel right in the centre. Surrounding this central naked female flower are seen five groups of naked male flowers produced from the inner side of the hollow receptacle. Each group of male flowers is a minute cluster and is seen to be a scorpioid cyme. The naked male flower consists merely of a single stamen with a filament articulated at the top. Very often the involucre carriès at the edge one to four glands secreting nectar. The glands may develop petaloid outgrowths which make the cyathium attractive. The central female flower is usually inclined to one side. In some species, the upper surface of the terminal

leaves close to the cyathia are coloured and the cyathia are made conspicuous. Cyathia occur in large numbers and may be arranged in umbel-like clusters.

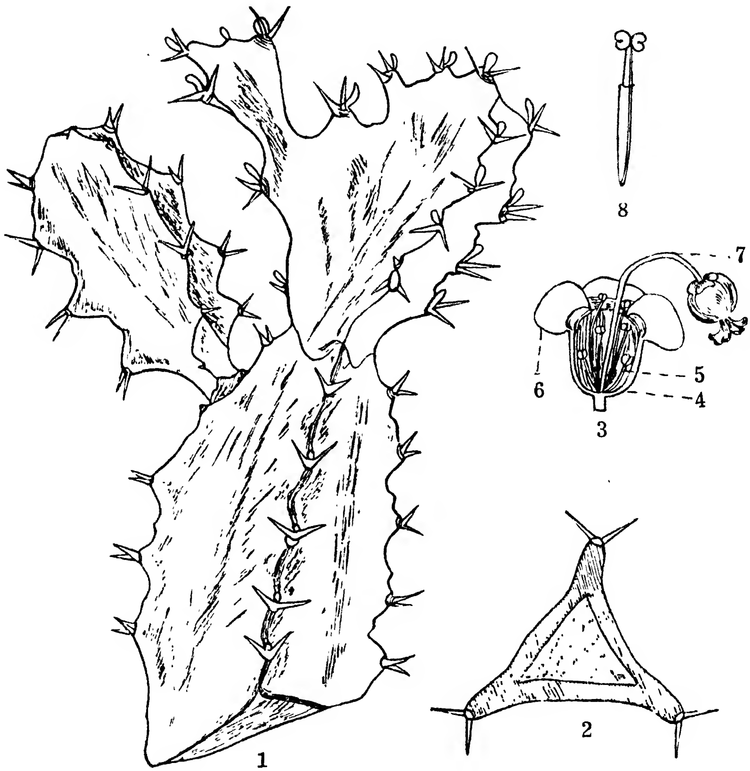


Fig. 210. Euphorbia : 1. Shoot ; 2. C. S. of the shoot ; 3. L. S. of a cyathium ; 4. Involucre ; 5. Staminate flowers ; 6. Petal-like outgrowth on the gland ; 7. Pedicellate pistillate flower ; 8. A single naked staminate flower.

(Summary at the end of Chapter XXI.)

CHAPTER XXI

FAMILIES: MONOCOTYLEDONS

The monocotyledons form a small group compared with the dicotyledons and most of them are small perennial herbs. They show certain general characteristics which help us to distinguish them easily from the dicotyledons. The roots are adventitious and the tap-root ceases to grow at an early stage. The shoot is sparingly branched and the leaves generally show parallel venation. Stipules are wanting and the stem shows very little increase in thickness. The flowers are small and their parts are arranged in threes. Trimerous arrangement of the floral parts (arrangement in threes) is characteristic of the monocotyledons as against the tetramerous or pentamerous type (arrangement of the parts in fours or fives) common in the dicotyledons. The perianth is not usually clearly differentiated into a calyx and a corolla and the segments are similar in most cases. The embryo of the monocotyledon has only one seed-leaf as against the two seed-leaves in dicotyledons. To the monocotyledonous group belong the Palms, the Lilies, the Aroids, the Orchids, the Plantain, and the Grasses. Only two families will be taken up for detailed study.

Palmae

A large family common in tropical parts. Trees (rather exceptional in the monocot); trunk unbranched; of uniform thickness all along; with a crown of leaves at the top; scars of leaves large and close together.

Leaves. Large, in a tuft forming a crown at the top; folded when young either pinnately or palmately; looking like a long narrow sword; the pinnately folded type giving rise to the feather type of compound leaf through the disorganisation of cells at the region of the folding; the palmately folded type giving rise to the fan-type of leaf which is palmately lobed in

the adult stage; petiole stout; leaf-base sheathing; leaf falling off completely and leaving smooth leaf-scars or leaving remnants so as to make the trunk appear rugged.

Flowers. Unisexual; monoecious in most cases; in a peculiar spike; the entire spike being enclosed by a huge tough bract or *spathe;* the axillary spicate inflorescence with unisexual flowers enclosed by the spathe being termed a *Spadix;* the spathe opening lengthwise and exposing the cluster.

Fig. 211. Cocos nucifera (Spadix): 1. Spathe; 2. Staminate flowers; 3. Pistillate flower.

Male.

Cal. 3; small; valvate.

Cor. 3; somewhat horny valvate.

Sta. 6; polyandrous.

A reduced or ill-developed pistil, called *pistillode* may be seen in the male flowers in some forms.

Female.

Cal. 3; comparatively large; imbricate; persistent.

Cor. 3; comparatively large with imbricate tips; persistent.

Pist. Syncarpous; ovary 3-celled but only one developing in most cases; one ovule; stigma almost sessile; fruit drupe-like or nut-like; seeds albuminous; cotyledon highly specialised during the germination of seeds.

EXAMPLES

Cocos nucifera. The Coconut. A very common palm abundant on the coastal region and also common in the inte-

rior, very useful. Leaves feather-type ; flowers monoecious ; in branching spikes ; perianth in female flowers becoming big ; fruit one-celled and one-seeded ; endosperm hollow, rich in oil and known as *copra* in commerce.

Borassus. A palm common in dry districts ; leaves of the fan-type ; flowers dioecious ; male flowers embedded in brown branching club-shaped bodies with several spathes. Fruit 3-celled with 3 pyrenes.

Areca catechu (The Betel-nut palm). An elegant palm largely cultivated for the betel-nut ; internodes clear ; flowers monoecious ; endosperm ruminate.

Calamus. The Cane palm ; a powerful scrambler with numerous recurved emergences on the leaf. Stem long and slender with long internodes, very useful.

Phoenix sylvestris. Ovary of 3 free carpels ; flowers dioecious ; allied to the Date palm ; fruit fleshy.

* * *

Musaceae

This is really a sub-family of a big family common in South India. This sub-family is represented in South India by the solitary genus *Musa,* the Plantain type. Perennial herb with a short thick subterranean rhizome ; presence of a sticky fluid is noticed ; adventitious roots soft and thick ; aerial shoots developing rapidly and showing a trunk-like body with a crown of leaves ; the trunk-like structure not a real axis or trunk but formed by the close and regular overlapping of the large successive sheathing leaf-bases by their edges ; the real axis being slender and covered by the cluster of sheathing leaf-bases.

Leaves. Radical ; spirally placed ; blade large and convolute with pinnate parallel venation ; leaf-stalk stout and deeply grooved ; leaf-base long and concave ; sheathing ; overlapping regularly ; air-cavities numerous.

Flowers. A conical cluster on the top of the slender axis of the aerial shoot, which comes into view at the time of

flowering ; a kind of spadix ; flowers sessile in two close rows in the axil of each of the numerous overlapping spathes arranged in a close spiral on the axis ; irregular and epigynous ;

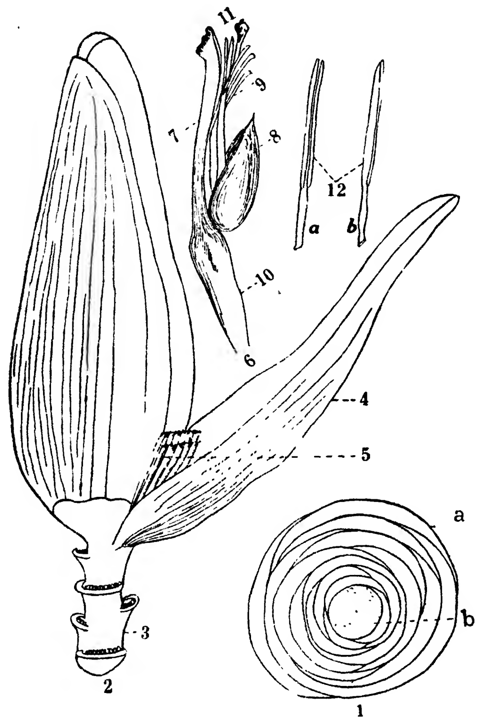


Fig. 212. Musa : 1. C. S. of the aerial shoot : a. Leaf-base, b. Axis ; 2. Spadix ; 3. Axis ; 4. Spathe ; 5. Cluster of flowers ; 6. A flower ; 7. Anterior perianth ; 8. Posterior perianth ; 9. Stamens ; 10. Ovary ; 11. Stigma ; 12. Stamens ; a. Front view, b. Side view.

some of the flowers behaving like unisexual flowers through the inability of the stamens or the pistil to function.

Cal. 3 ; *Cor.*, 3. The perianth consists of two parts, a smaller posterior glistening part overlapped completely by a larger anterior part which is five toothed ; superior.

Sta. 6 ; epigynous, one opposite to each segment of the perianth ; the stamen opposite to the odd posterior perianth

is either reduced to a staminode or even completely suppressed ; filaments stout ; anthers adnate, connective prolonged beyond the anther lobes.

Pist. Syncarpous ; ovary inferior ; 3-celled ; ovules many ; placentation axile ; style single ; stigma capitate (head-like mass) ; fruit berry ; seeds not well developed.

EXAMPLES

Musa. The plantain with so many varieties ; largely cultivated ; propagation in a vegetative manner through the subterranean stem.

A species of Musa growing in the Philippine Islands gives the fibre, Manilla Hemp.

Ravenala (the Traveller's Palm). An African tree with a real trunk and with large leaves arranged in two rows on the top of the real trunk is grown in some gardens.

SUMMARY

Plants may be classified according to their resemblance. The classification of plants is based on a comparative study of the characteristics of all the organs of the plant-body in different plants.

Similar individuals are grouped into species, allied species are grouped into genera, and allied genera are grouped into families ; and plants of all types are brought under the Vegetable kingdom on the ground that they possess the green pigment.

The aim of classification is to arrange plants according to their blood-relationship. Charles Darwin was a great naturalist and thinker and the idea of blood-relationship was emphasized by him.

The Binomial Nomenclature is a very convenient method and we owe this system to Linnaeus.

The Dicotyledons form a much bigger group than the Monocotyledons and are easily distinguished from them.

Each family shows a definite combination of characters and the plants included in each family show great resemblance in regard to chief features alongside of differences in details.

Many of the plants like the Cotton, the Pulses, and the Palms are of great economic value.

CHAPTER XXII

FLOWERLESS PLANTS: THE FERNS

General. Flowerless plants form a big group and they are so called because they do not produce flowers. This class consists of forms which vary a good deal in size and form and structure. Some are very minute organisms which can be recognised only under the microscope. On the other hand, there are plants which may resemble the flowering plant in regard to the construction of their body. The group of flowerless plants used to be called *cryptogams* and it will be interesting to study the structure and life-history of the different forms arranged under the following sub-groups: (1) The Ferns, (2) The Mosses, (3) The Algae, (4) The Fungi, (5) The Lichens, and (6) The Bacteria.

The Ferns—Habitat and Habit. The ferns are generally small perennial herbs occurring in warm and humid regions. They are more abundant in the hills in our province and they commonly grow in the shade. In the forests of the Western Ghats there are some ferns which grow into elegant trees or manage to climb up. A few do not have any connection with the soil; and they occur on the branches of trees and carry on their activities. Such forms are described as *epiphytes* and their easy-going habit is due to the fact that conditions are very favourable for the growth of plants in such forests. Visit the Fern House in the Botanical Gardens and you will have an idea of the habit and wonderful variety of form in ferns.

The Body. The body of the fern plant consists of the root, the stem, and the leaf. The roots are adventitious and arise from the stem close to the leaf. They are like the normal roots of flowering plants. The stem is insignificant in the majority of herbaceous ferns and it takes the form of a short rhizome which is obliquely placed in the soil. In certain forms, the rhizome may be long and may grow horizontally in the soil. The rhizome has its older portion covered with

the remnants of the leaves which are arranged in a tuft owing to the short nature of the axis. The leaves are very

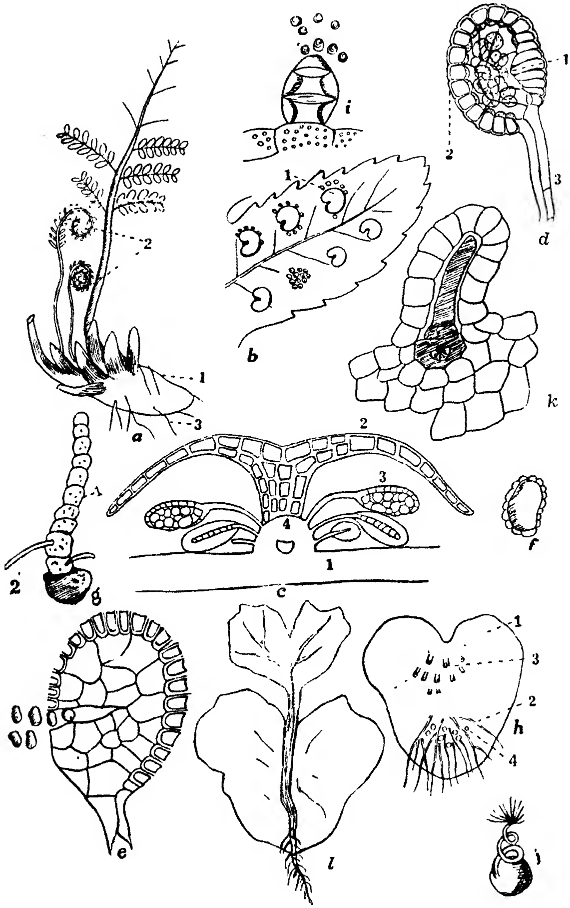


Fig. 213. The Fern : a. The Fern plant : 1. Rhizome, 2. Young leaves, 3. Roots ; b. A leaflet : 1. Sorus ; c. C. S. of the leaf at the region of the sorus : 1. Leaf, 2. Indusium, 3. Sporangia, 4. Protuberance from the lower surface of the leaf d. A sporangium : 1. Spores, 2. Annulus, 3. Stalk ; e. Sporangium dehiscing f. Spore ; g. Spore germinating : 1. Young filamentous stage, 2. Rhizoid ; h. Prothallus : 1. Front part, 2. Rhizoids, 3. Archegonia, 4. Antheridia ; i. Antheridium opening ; j. A spermatozoid ; k. Archegonium : l. Prothallus (after fertilisation) with the young fern plant. (Adapted from several sources).

large and form the prominent portion of the plant. One can easily recognise a fern by its leaves which are always coiled

when young from the tip to the base. These are described as *circinate* owing to this peculiar vernation. The leaves are often compound or decompound and the rachis is covered with hairy or scaly outgrowth, especially when they are young. The leaflets are traversed by ribs which show a tendency to fork repeatedly and the veins may not be distinct in certain cases. The fern leaf continues to grow for a much longer period than that of the flowering plant and the tree-ferns found in forests carry very big leaves in the form of a crown at the top. The ferns are organised in much the same manner as the flowering plants. As for the internal structure, you can see that the organs of the fern plant possess the same kinds of tissues, namely, the epidermal, the fundamental and the vascular tissues. The general differentiation into tissues may be the same but there are certain interesting points of difference in details. For instance, the xylem does not contain long vessels and the conducting tubes known as *tracheids*, are simple individual cells which have become somewhat elongated. There is no cambium in the vascular bundle and the fern stem does not show any great increase in thickness.

Normal activities. Since the body of the fern plant is built on the same lines as those of a flowering plant, it is natural that it will perform its function in a similar manner. The roots act as the fixing and absorbing organs. The leaves are the assimilating organs and they possess a mesophyll which prepares carbohydrates and other materials.

Reproduction and life-history. The fern can reproduce itself vegetatively by adventitious buds which appear at the tip of the leaf. When the tip of the leaf comes into contact with the soil, the bud strikes root, and with the decay of the original leaf, the new shoot becomes an independent plant. Flowers are never produced on the fern plant and its reproduction is different from that of the flowering plant. You may ask what part the fern plant takes in the matter of reproduction. Examine the under surface of the fern leaf carefully and observe the numerous little kidney-shaped structures scattered on the surface close to the veins. If you touch any of these bodies, many small brown particles

will be adhering to your finger. These particles are the germ bodies or spores which have a part to play in connection with reproduction. Remove one kidney-shaped brown body, tease it with the needle, and examine it under the microscope. The kidney-shaped body is by no means simple. It has got a membranous covering which encloses a large number of stalked, bag-like structures attached to a mass of tissue. Inside each bag are produced many spores as minute particles. Each bag should therefore be regarded as a *sporangium* whose purpose is to produce *spores* asexually. The kidney-shaped body (Fig. 213-b) is really a cluster of sporangia and is called a *sorus*. The membranous covering which can be easily recognised even with the naked eye is called *indusium* which protects the sporangia. **The fern-leaf is not a mere assimilating body but it is also concerned with the production of spores. It may, therefore, be considered a sporophyll.** While, in several ferns, the ordinary leaf may itself be serving as the sporophyll, a distinction into fertile and sterile leaves or a distinction into sterile and fertile parts in a leaf is also noticed in certain forms.

Sorus and Sporangia. What is the relation between the sorus and the leaf ? A section of the leaf (Fig. 213-c) at the fertile part shows at certain points on its under surface, small protuberances whose free ends dilate into a flat shield-shaped membrane or *indusium.* From the sides of the protuberance, outgrowths arise which develop into stalked sporangia. Each sorus is supplied with plenty of materials on account of its close connection with the leaf. The sorus may be of different forms and sometimes the cluster of sporangia may be protected not by a separate indusium but by the folding of the margin of the leaflet itself. The body of the sporangium (Fig. 213-d) consists of an one-layered thin wall enclosing the spore-producing tissue. The wall is very thin except along one region. This region which appears as a band or row of thick-walled cells is called *annulus* and the inner and lateral walls of the cells of the annulus are specially thickened. This annulus does not form a complete band throughout the sporangium. It begins from the top of the stalk, goes up the sporangium along one

side and extends only half way down to the other side. The peculiar nature of the annulus helps the opening or dehiscence of the sporangium when it becomes ripe. Inside the young sporangium, cell-division proceeds along definite lines rapidly and there is finally produced a mass of young cells rich in protoplasm. Each cell in this tissue becomes a spore-mother cell which divides to produce four spores. A definite number of spores, say 48 or 64, is produced in each sporangium and owing to the large number of sporangia borne on each leaf, the output of spores is considerable. When the sporangium is ripe, the wall gives way (Fig. 213-e) at the thin part where the annulus ends. The spores come out and are easily carried away by wind since they are only small dry particles. Each spore (Fig. 213-f) is a single cell with cytoplasm and nucleus and with a wall differentiated into an outer thick layer and an inner thin layer. The protoplast is rich in organic materials. The spores are similar to one another and are of one kind. Hence the fern plant may be regarded as *homosporous*. The spores are germ-bodies which begin to germinate elsewhere under favourable conditions and to give rise to a new generation. The spores are bodies produced asexually in the sporangium and the fern plant should be regarded as a spore-producing plant or *sporophyte*. Does the spore on germination produce a Fern ?

Germination of the spore. The spore begins to be active when it comes into contact with a moist substratum (Fig. 213-g). Its activity is quite independent of the fern plant that has produced it. As a matter of fact, the spore may have been carried a long distance away from the parent fern. When the spore absorbs water, it swells and the outer layer becomes ruptured where it happens to be thin. The inner layer with the contents protrudes and cell-division takes place in the protruding part. The cells are arranged end to end to form a short filament first of all. Chloroplasts appear in the cells of the short filament which produces a few short hairy processes which fix the filament to the soil. After a time, the daughter cells which are produced, are arranged in two dimensions and as a result the filamentous body grows into

a small, flat, thin, and green body, called *prothallus* (Fig. 213-h). Owing to difference in the rate of growth, the prothallus becomes finally heart-shaped and it lies flat on the ground with a dorsal upper surface facing the sky and a ventral lower surface in contact with the earth. By this time numerous colourless hairs are produced on the under-surface close together and these are mere prolongations from the under-surface. These hairs which are called *rhizoids*, are able to fix the prothallus firmly to the soil and also to absorb water and salts from the soil. *The prothallus which is a small simple flat green body thrives well on a moist substratum.* It is thin at the margin while it is slightly thick along the middle. It is able to lead an independent life with the help of its rhizoids and chloroplasts. The spore has, as the result of germination, produced an independent individual no doubt, *but the individual or prothallus is altogether strange and shows no resemblance to the parent fern.* How to get the fern plant from a fern plant is still a problem! The spore produced by the fern takes us perhaps only half-way or through one-half of the life-history. What is the purpose of the prothallus ?

Sex organs. The prothallus produces in a short time on its under surface two kinds of sex organs. One kind which produces the active male gametes or spermatozoids is called the *antheridium* and the other kind which produces the stationary egg is called the *archegonium.* The antheridium or sperm apparatus (Fig. 213-i) is small and rather spherical and it appears in large numbers on the under-surface of the prothallus near the narrow part while the archegonia (Fig. 213-k) are flask-shaped bodies found usually on the same prothallus near the broad region. The lower rounded part of the archegonium is embedded in the thallus while the neck is protruding into the substratum. The antheridium has got a wall enclosing a sperm producing tissue. Inside each cell in this tissue, a male gamete is produced which is club-shaped and carries numerous cilia at the narrow end. The antheridia open and the cells in which the male gametes are produced come out. Very soon the male gametes escape

from the cells and swarm about in the drops of water. These gametes are sperms which, on account of the capacity for movement, are called *spermatozoids* (Fig. 213-j). The spermatozoid is cork-screw-shaped. At the tip are to be seen numerous cilia with the help of which the spermatozoids are able to move of their own accord and to find their way to the egg. The presence of water is essential for the movements of the spermatozoid and drops of water will not be wanting close to the prothallus which grows on a moist substratum. The spermatozoids are spirally coiled, multi-ciliated, and actively motile gametes which swarm aimlessly at first.

The archegonium or egg-apparatus, as it is commonly called, is a flask-shaped body. The lower broad portion is in close contact with the thallus and in this part the big egg is differentiated. The long neck which happens to be slightly curved protrudes towards the outside or the substratum. This neck consists of a number of cells arranged in regular rows and it is not necessary for our purpose to mention all the details of structure. The egg which is placed lower down in the prothallus is in contact with the substratum through the neck. When the archegonium is ripe, the neck bursts at the free end and there exudes a substance containing malic acid into the substratum. The spermatozoids which have been swarming aimlessly are now attracted towards the archegonia. This chemical attraction is significant since it directs the sperms towards the egg. These move towards the archegonium and several try to get into the neck. One succeeds in reaching the egg and then loses its cilia. The sperm substance mixes with the egg and this fusion is *fertilisation.* But for the presence of water, the movement of the spermatozoids will become impossible and fertilisation can hardly take place. It is interesting to note that the spermatozoids are themselves able to find their way to the egg in the fern. The essential principle of fertilisation, namely, the fusion of the sperm with the egg is the same whether it is the fern or the flowering plant. How the sperm manages to reach the egg is an entirely different question.

The Embryo. Fertilisation acts as a stimulus and the fertilised egg surrounds itself with a wall. It then begins to divide in the prothallus and a cell-mass is produced. In this cell-mass the different parts of the future fern plant are beginning to be differentiated. Thus the microscopic fertilised egg is developing into an embryo. The embryo shows the radicle, the plumule, and the first leaf and, in addition, a massive cushion known as *Foot* (Fig. 214-a) which is embedded in the prothallus. This foot is rather prominent and the differentiation of the foot at an early stage is necessary because it absorbs materials from the prothallus and makes the rapid development of the embryo possible. This embryo is now far too big for the base of the archegonium and its parts come out. The radicle grows down and becomes the first root. The first leaf (Fig. 213-l) makes its way up through the notched tip of the prothallus. A small fern or fernling is now seen ; and the foot and the prothallus disappear. In the meantime rootlets are produced which fix the little fern firmly to the soil and the leaf also becomes large and green. A fern plant which is of the same kind as the original fern has thus been produced.

From Fern to Fern. The life-cycle of the fern is interesting. The journey from fern to fern is not completed at one step. **There are really two distinct phases in the life-cycle or life-history of the fern plant. There is one phase, the phase of the leafy fern plant ; and the simple prothallus represents the other phase.** These two phases occur independently and, as a matter of fact, the two phases may be regarded as independent generations. The highly organised fern plant is to produce the asexual bodies or spores and it is therefore treated as the spore-producing *asexual* generation or *sporophyte*. The prothallus is to produce the two kinds of sex-cells or gametes connected with the fertilisation process. The prothallus is therefore termed the gamete-producing *sexual* generation or *gametophyte*. There is one interesting feature to be noticed in the life-history. **The two distinct phases regularly alternate with each other in order that the life-cycle may be completed.** The sporophyte produces spores which give rise to the gametophyte ; and the fusion of the gametes in

the gametophyte produces the fertilised egg which is the starting point of the sporophyte. The sporophyte is followed by the gametophyte which is then followed by the sporophyte and so on. **This alternation of two distinct and independent generations is very clear in Ferns.**

The sporophyte phase which is represented by the fern plant is more prominent, more highly organised and more enduring. It possesses well-defined organs such as the root, the stem and the leaf and the tissues are clearly differentiated. Moreover, the fern plant is fitted to live on land and its roots

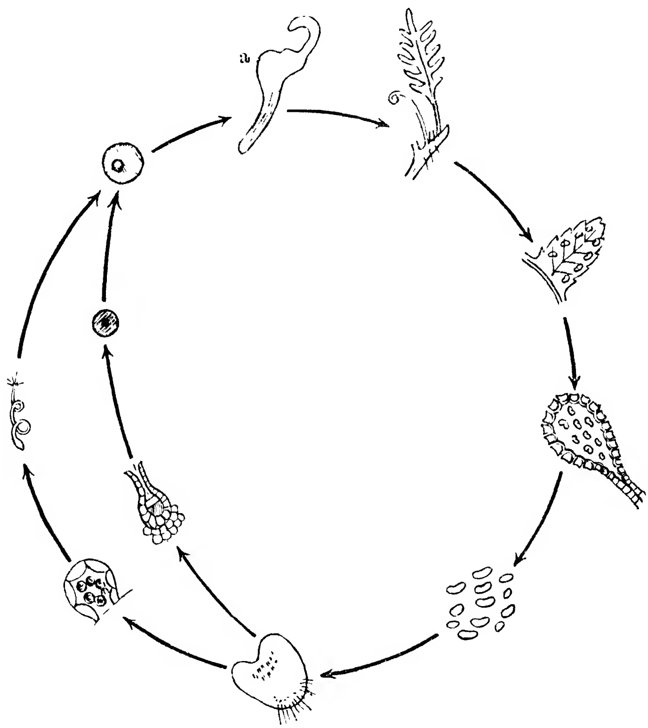


Fig. 214. Life-cycle of the Fern : a. Embryo with foot.

fix it firmly to the soil. Take the case of the gametophyte. It is a small, tender, flat, thin and green thallus. Its body is very simple and shows no differentiation worth mentioning. The rhizoids are mere outgrowths which are single cells and can-

not be compared with the roots. Further, the prothallus lies flat on the soil and is adapted for growing in very moist conditions. This moist substratum which is necessary for the growth of the prothallus is favourable for the occurrence of fertilisation. There is great force in the statement of Prof. Bower that the Ferns form a group with one foot on land and another in water. The life-cycle of the fern may be illustrated graphically as in Fig. 214.

SUMMARY

The ferns form a very important group of flowerless plants and are highly organised. There are two independent generations in their life-history and these alternate regularly with each other. The asexual generation or the sporophyte is better organised and is fitted to live on land. The sexual generation is reduced to a thallus which is very simple in structure. The prothallus is a moisture-loving form with a green thallus fixed to the soil by brown rhizoids.

CHAPTER XXIII

THE MOSSES

Habit and Habitat. The mosses are small tender plants which occur in very large numbers immediately after rains in the crevices of walls or in shaded moist situations. In forests, the surface of trees is often covered with a dense growth of mosses. Wherever mosses occur, they are found close together in such large numbers that they form a green mat on the substratum. Many of the mosses are erect forms while some are of the creeping type.

The Body. The moss plant has a tender axis varying from ¼″ to 1″. The lower end of the axis shows brown multi-cellular hairs or rhizoids which grow in the soil and act as fixing organs. The rhizoids (Fig. 215-h) are branching and spreading rapidly and are able to absorb water and salts from the soil. They are not to be compared morphologically with the root of higher plants. The upper part of the axis may be simple or branched and it carries in a close spiral a number of small leaves which may sometimes be clustered at the top. The leaves are small, simple and sessile ; and their bases are sheathing. They are thin and green. The sides of the blade are very thin, while the mid-rib region is thick. There is nothing like ribs or veins in the blade and the blade is made up of simple cells. The rhizoids, the stem, and the green leaves form the organs of the moss plant. These may perform the functions of the corresponding structures in higher plants but differ really from them in their nature and structure. The internal structure of the different organs shows no great tissue-differentiation. The tissues which are clearly noticed in the organs of higher plants are not to be seen in the moss though there may be some attempt at differentiation in the stem. No vascular bundles are developed in any part of the plant body which may be considered as being built up mostly of simple cells.

Normal activities. Though the body of the moss plant is far simpler than that of higher plants, it can carry on all

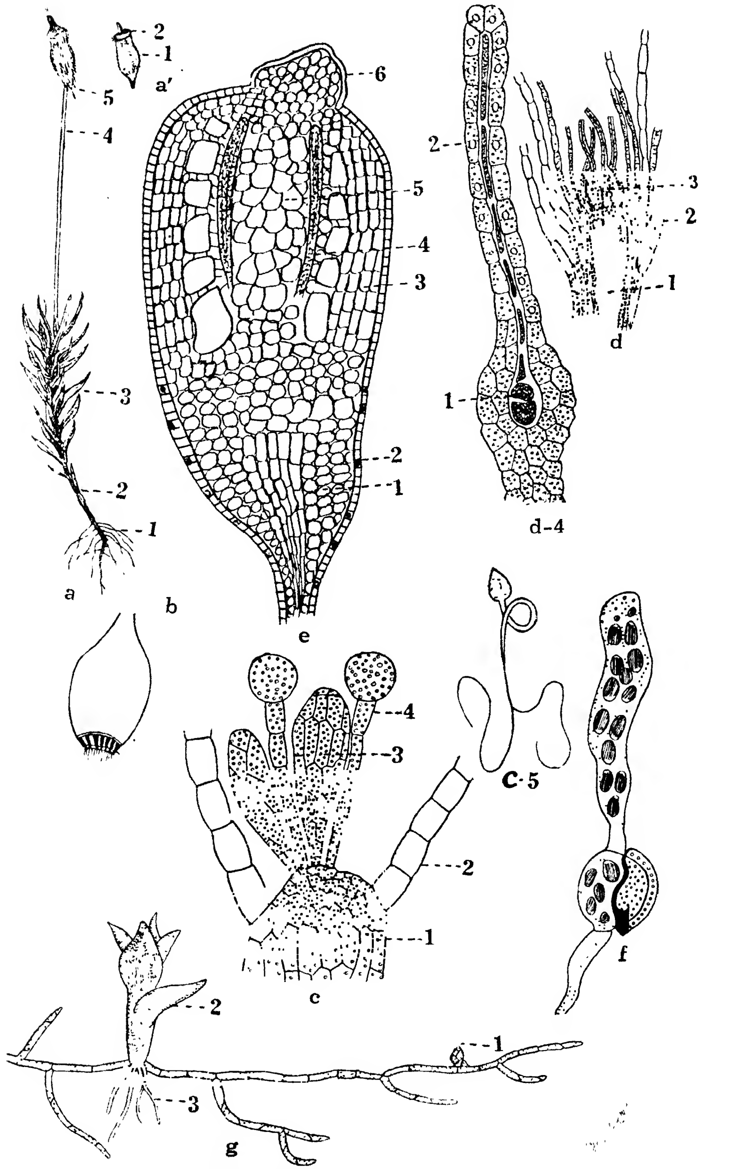
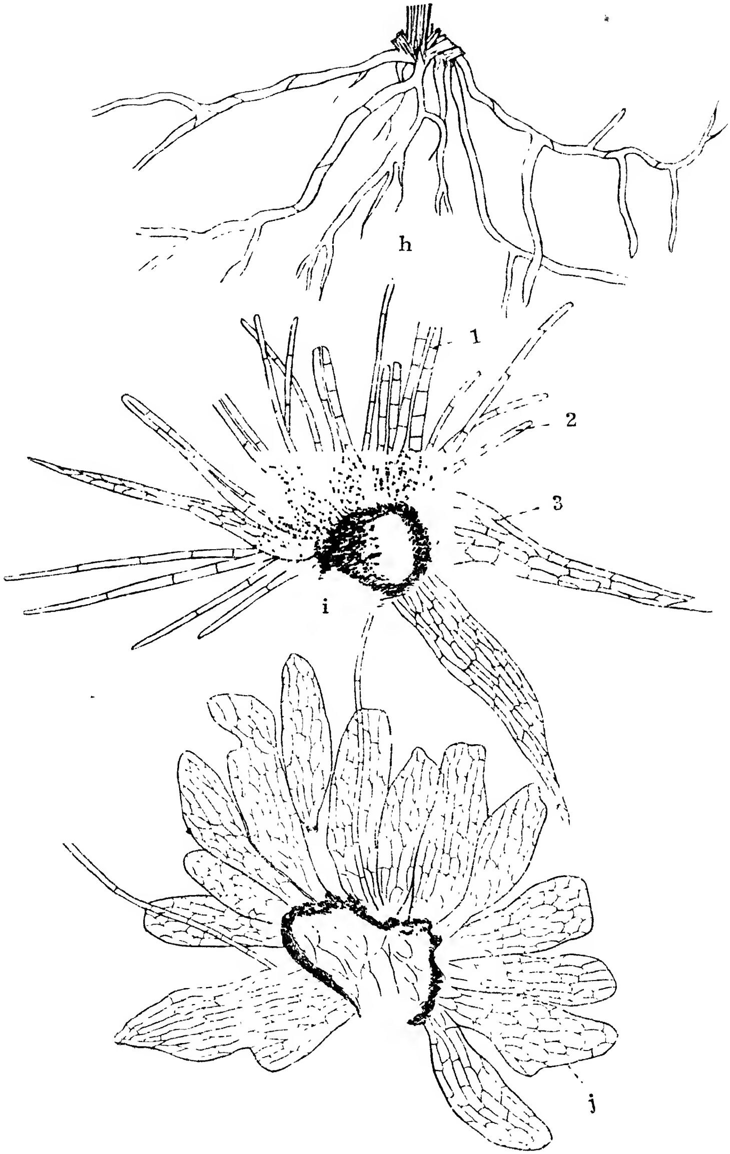


Fig. 215. The Moss : a. A Moss plant : 1. Rhizoids, 2. Stem, 3. Leaves, 4. Seta, 5. Sporogonium with calyptra ; a′. Sporogonium without calyptra : 1. Capsule, 2. Operculum ; b. Ripe capsule, showing the peristome teeth at the broad part on opening. c. Tip of the male shoot : 1. Axis, 2. Outer leaves, 3. Antheridia, 4. Paraphyses, 5. Spermatozoid ; d. Tip of the female shoot : 1. Axis, 2. Outer leaves, 3. Archegonia, 4. One archegonium : 1. Venter with egg, 2. Neck ; e. L. S.



of the capsule : 1. Apophysis, 2. Stomata, 3. Upper wall-layers, 4. Fertile or spore-producing layer, 5. Columella, 6. Operculum ; f. Spore germinating ; g. Protonema : 1. Bud, 2. A small Moss shoot, 3. Rhizoids ; h. Rhizoids enlarged and branching ; i. Archegonia at the tip of a shoot : 1. Archegonia, 2. Paraphyses, 3. Leaves ; j. Antheridia at the tip of a shoot.

(Adapted from several sources.)

the normal activities like any of the higher plants. The rhizoids are the absorbing organs while the leaves are the assimilating organs. The stem places the leaves in a favourable position. One peculiarity with many moss plants is their capacity to withstand extreme drought. They may appear dry but with the first shower they show signs of activity.

Reproduction and life-cycle. Vegetative propagation is possible through buds that develop on thread-like structures. The normal life-history shows an alternation of generations as in the fern. What does the moss plant produce ? At the apex of each moss shoot is borne a cluster of sex-organs (Fig. 215). The sex-organs are of two kinds : (1) the sperm-apparatus or antheridium and (2) the egg-apparatus or archegonium. The antheridia and archegonia are borne at the apex of separate moss shoots. Take the antheridial shoot (Fig. 215-c and j). The axis slightly dilates at the top and the leaves near the top surround the antheridia. The antheridia are spindle-shaped or club-shaped structures, each consisting of a wall enclosing a sperm-producing tissue. Intermingled with the antheridia are also seen peculiar multi-cellular hairs known as *paraphyses*. Each cell inside the antheridium produces a spermatozoid which is, in the case of the moss, **bi-ciliated**. When the ripe antheridium opens, the cells containing spermatozoids come out and the spermatozoids then leave the cell. They swarm about in the drops of water in the moist substratum. The spermatozoids move aimlessly for a time and they are then attracted towards the archegonium by a fluid containing cane sugar.

The Archegonium is a flask shaped structure which occurs in large numbers at the top of the archegonial shoot (Fig. 215-d and i). As in the case of the antheridial shoot, the leaves near the top surround the archegonia and paraphyses are also intermingled with them. The basal round portion containing the egg is not embedded in the moss shoot. The neck is very long and consists of several cells arranged in a number of rows. The egg in the venter is well-protected and is prominent. When the archegonium is ripe, the neck opens at the top and a fluid

containing cane sugar exudes. Several spermatozoids are attracted towards the archegonium and one of them manages to glide down the neck and reach the egg. The cilia are lost and the sperm fuses with the egg. The presence of water is absolutely necessary for the sperms to move about as in the ferns. Otherwise, the sperms cannot reach the egg.

The Capsule. The fertilised egg is the starting point of a new generation. It forms a wall around it and begins to grow. It becomes enlarged and shows great activity. It gives rise to a mass which becomes an embryo differentiated into three parts, (1) a short *foot* at the base, (2) a prominent fruit-like portion or *capsule* at the free end, and (3) a short stalk in the middle. At first the base of the archegonium is able to accommodate the growing embryo. Very soon the stalk begins to grow more in length and the upper part of the archegonium is ruptured. The stalk with the capsule comes out and the ruptured upper part of the archegonium happens to be carried along with the capsule on its top. The fertilised egg has now grown into a stalked capsule which is yet kept in close connection with the moss shoot by the foot. The new generation into which the fertilised egg has developed remains in contact with the moss shoot and it is peculiarly constructed. The foot serves to absorb materials from the moss shoot and to pass them on to the growing capsule. The capsule is the most important part and the stalk on which it is borne is termed *seta.* The stalk keeps the capsule in position and serves to push it up in air. The capsule is a fruit-like body and is green at first. It is intended to produce inside a large quantity of spores and is therefore called *sporogonium.* The ruptured part of the archegonium which is found to cover the young capsule like a hood for a time is called *calyptra* and it falls off later on (Fig. 215-a. 5). The capsule is found to be inclined in many cases owing to the curving of the stalk and it shows a complex structure. There is a marked constriction at the top and the part beyond the constriction is known as the lid or *operculum.* If the capsule be cut lengthwise and examined under the lens, the lower part is seen to be compact and sterile while the broader

upper part alone produces spores. Observe a section of the young capsule under the microscope (Fig. 215-e). The capsule shows a multi-layered wall and the outermost layer is like the epidermis. The lower sterile region is interesting because the epidermis in this part shows stomata and the parenchymatous tissue inside is rich in chlorophyll. The lower green sterile part is capable of preparing organic materials and helping the capsule to grow. This assimilating part of the capsule is called *apophysis.* The spore-producing tissue does not fill up the entire upper portion. In the centre of the upper part there is seen a massive sterile tissue which is called *columella.* Immediately outside this central columella and between it and the multi-layered wall is seen a narrow region consisting of cells. This narrow zone alone represents the fertile part and the numerous cells divide to produce small spores. The fertile zone does not extend beyond the constriction region into the operculum. In some cases the fertile layer may be separated from the wall layers by large air-cavities traversed by rows of cells. As the capsule ripens, it loses its green colour and turns brown. The parenchymatous tissue dries up and the entire capsule looks like a bag in which the spores are lying loose. At the ripe stage, the operculum separates itself and falls off as a lid. As the operculum falls off there appears at the edge of the capsule a circle of stiff hairs or tooth-like processes. These persist and form the *peristome.* There is a purpose served by the peristome which is hygroscopic. In dry weather, the teeth of the peristome become spread out. The capsule is opened and the spores can readily come out. In wet weather which is not favourable for the distribution of spores, the teeth close up the passage and do not allow the spores to get out.

Spores. These are all of one kind and they are single cells. On leaving the capsule these are carried by wind and they germinate on coming into contact with a moist substratum. They absorb water and swell. The outer layer is ruptured at a weak spot and the inner layer with the contents protrudes. The protruding part begins to divide and a short filament con-

sisting of a row of green cells is formed and it is spreading on the surface. The cells of the filament contain chloroplasts and become active. The filament becomes much branched and the branched filament produces short brown rhizoids here and there. A much branched green thread is produced and this is called *protonema* (Fig. 215-g). The protonema is fixed to the soil by brown rhizoids and very soon many buds appear at different points on the green protonema. Each of these buds develops into a moss shoot with axis, leaves, and rhizoids. From one spore that has begun to germinate, a cluster of moss shoots is formed since numerous buds are produced on the protonema. The protonema threads may decay but numerous moss shoots have appeared by this time and these are clustered together. The protonema is a convenient device to increase the number of shoots. Considering that the output of spores is not as great as in ferns, the protonema stage should be regarded as really valuable.

From Moss to Moss. In the life-history of the moss also **there is an alternation of two generations.** The sexual generation is represented by the moss plant and it is more prominent and better organised. The moss shoot is the gametophyte or sexual generation which is accustomed to grow in moist situations. It is able to lead an independent life and the protonema stage is a temporary device to increase the number of shoots. The process of fertilisation takes place in the moss shoot and the stalked capsule is the result of the development of the fertilised egg. This stalked capsule is really the sporophyte if, by sporophyte, we mean the generation that produces spores. The sporophyte is differentiated into a foot, a stalk and a capsule. While in ferns and other higher plants, the sporophyte is more prominent and more highly differentiated into stem, roots and leaves, the sporophyte of a moss is reduced to the minimum and it is a mere spore producing structure. There is one important point in the life-history of the moss. **The sporophyte is a separate but not an independent generation.** Throughout its development it is attached to the gametophyte generation and it also derives materials from it. No doubt, the capsule which forms part of the sporophyte can prepare

organic materials but yet the dependence of the sporophyte on the gametophyte is unmistakable. The sporophyte generation of the moss never leads an independent life. It is clear that the moss forms a far simpler group than the fern and the flowering plant.

Life-cycle. The life-cycle may be graphically illustrated as follows: —

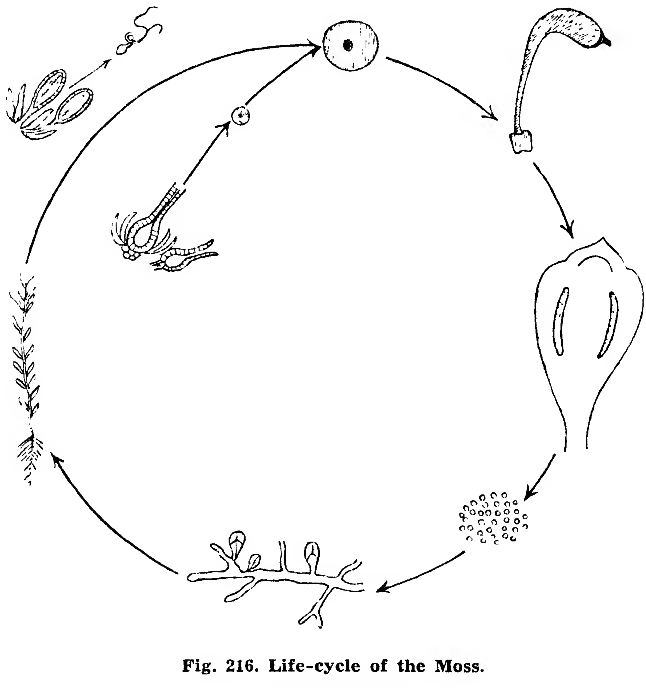


Fig. 216. Life-cycle of the Moss.

SUMMARY

The mosses are lowly organised and are found in large numbers on a moist substratum.

There are two generations alternating with each other but the gametophyte generation is independent, and much better organised. It shows a body differentiated into an axis fixed by rhizoids and carrying leaves higher up.

The sporophyte generation is remaining attached to the gametophyte and in spite of the complexity in its structure, is to be regarded as a mere spore producing body.

CHAPTER XXIV

THE ALGAE

General. The algae form a group of lowly-organised plants which are far simpler than the mosses. They occur in tanks, ditches, and pools. Many thrive well even in the sea and become attached to rocks. The marine forms become very large in several cases and are commonly known as *sea-weeds*. These occur abundantly in the sea (Fig. 217 : 5 and 6) and their body may show a differentiation into an axis with a number of leaf-like appendages on it. There may

Fig. 217. Kinds of Algae : 1. A Diatom ; 2. Pleurococcus ; 3. Spirogyra ; 4. Cladophora ; 5. Caulerpa ; 6. Sargassum.

be seen on the body here and there root-like organs which fix the seaweeds to the substratum. The algae present a wide range of variations in size, form, structure, and reproduction and they are commonly divided, for convenience, into four sections according to the pigment present in the body : (1) the Green Algae, (2) the Brown Algae, (3) the Red Algae, and

(4) the Blue-green Algae. In the cells of all the algae there is chlorophyll in the chloroplast; but in forms other than the green algae, additional pigments are also present which obscure the chlorophyll. It will be convenient to take up a few common types for consideration before making a general study of the algae.

Chlamydomonas. This is a small microscopic unicellular alga which occurs in fresh water. It is a small, oval organism which is motile even in the vegetative stage. The body consists of a cell-wall enclosing the protoplast in which a single cup-shaped chloroplast can be seen at the broad end. There is a single nucleus and the interesting thing about the organism is the presence of two cilia at the narrow beak or anterior end. The cilia protrude through the cell-wall and help the organism to move from place to place. There are other interesting features in the organism which need not be

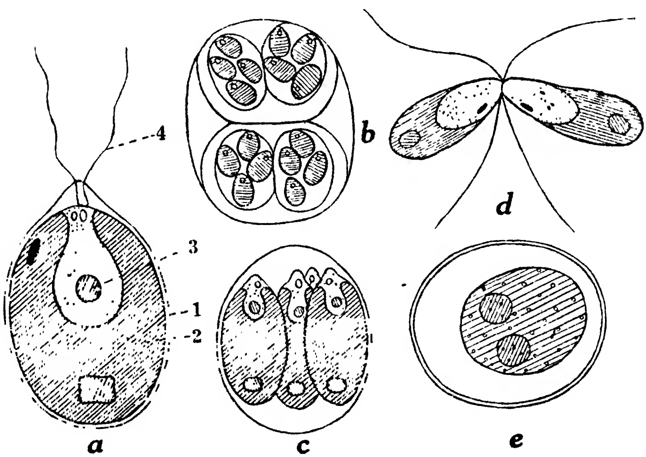


Fig. 218. Chlamydomonas: a. An individual: 1. Cell-wall, 2. Chloroplast, 3. Nucleus, 4. Cilia; b. Palmella stage; c. Protoplast dividing to form Zoospores; d. Conjugation in an allied form; e. Zygote. (Adapted from several sources.).

considered here. This motile form tends at times to become inactive and stationary. The cilia are lost, the protoplast divides, the daughter-bodies divide again, the wall becomes thick and slimy, and, consequently, several daughter-bodies are seen to occur together in a number of small clusters.

This condition which is known as the *palmella* stage is perhaps the resting time. The protoplasts inside escape after a time and the cilia appear so that the chlamydomonas form is resumed. The mode of reproduction is very interesting and it may be asexual or sexual. When the organism is about to reproduce asexually, the cell loses its cilia and the protoplast recedes from the cell-wall and divides into four daughter protoplasts (Fig. 218-c). Two cilia appear on each and the four bodies, usually called *zoospores,* should be regarded as asexual spores. Very soon, a cell-wall is developed round each and when the four bodies leave the mother cell they go away as new individuals. When conditions of life are favourable, asexual reproduction by zoospores goes on rapidly. Later on, other individuals show quite a different mode of reproduction. As in the case of the asexual mode, the individual loses the cilia; and the protoplast recedes and divides into eight or more daughter bodies. Two cilia appear on each and the several bodies leave the old cell generally as naked ciliated cells which are smaller than the zoospore. They look like zoospores but differ from them in behaviour. **Very often two such bodies show a tendency to come together and meet; and their cilia become entangled. Then the protoplasts fuse.** This fusion between two similar bodies has a stimulating effect and the body forming the product of fusion is able to develop. Hence the bodies that meet in pairs are to be regarded as **gametes**; and since fusion is between two similar gametes, the process is known as *conjugation.* Many interesting points of difference have been observed among the species of *Chlamydomonas* by investigators and they need not be dealt with now. The product of fusion is known as the *zygote* which loses the cilia and forms a thick wall. It passes through a resting period and begins to germinate when conditions become favourable. On the eve of the favourable season, the protoplast of the zygote divides first of all usually into four zoospores each of which on leaving the cell acquires a cell-wall and becomes a new plant. Thus four new individuals are produced when the zygote germinates. The asexual and sexual modes may be expressed in a general way as follows:—

(a) *Asexual mode.*

Chlamydomonas — Zoospores — *Chlamydomonas*

(b) *Sexual mode.*

Chlamydomonas — Gametes — Zygote — Zoospores — *Chlamydomonas*

Spirogyra. This is a very common alga met with in small pools and paddy fields. Its body is a simple, unbranched, green thread and it is visible to the naked eye. A number of plants occur together and float on the surface of water. This form is popularly known as the Pond Scum and it is somewhat

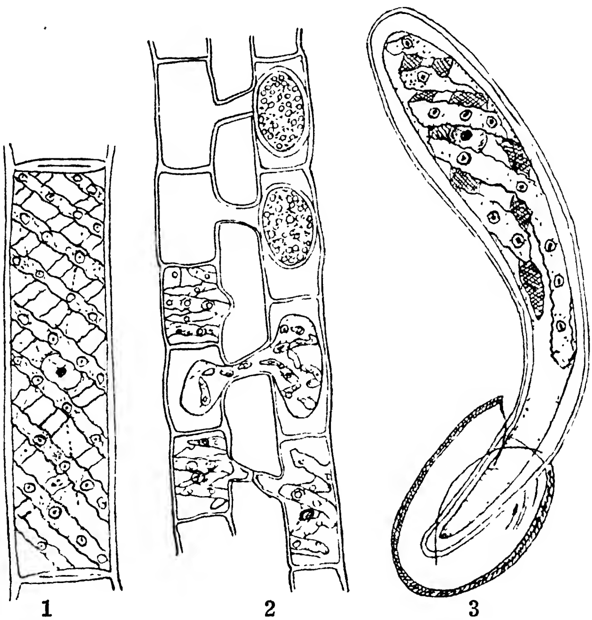


Fig. 219. Spirogyra : 1. A cell of the filament ; 2. Conjugation ; 3. Zygote germinating. (Adapted from several sources.).

slimy. When you examine the thread under the microscope, its structure becomes clear. It consists of a number of similar cells arranged end to end and is therefore a multicellular alga. Inside each cell there is a nucleus and the cytoplasm shows a few prominent ribbon-like chloroplasts traversing it in a spiral manner (hence the name *Spirogyra*). The cell-wall is quite distinct and there is no differentiation at

all in the body. Since the body is thread-like and since chloroplasts are present, *Spirogyra* is described as a *filamentous* green alga. No asexual reproduction by zoospores ever takes place in *Spirogyra* but vegetative reproduction through the breaking of the filament into bits can take place. The broken fragment can develop into a new individual. Sexual reproduction is common but it is of a very special type. Two filaments are found placed close together but parallel to each other and the cells of one filament are facing more or less those of the adjoining filament. Each of the cells of the two filaments puts forth a small protuberance on the side facing the other filament and the two protuberances from the opposite cells meet. Meanwhile the protoplast of each cell begins to recede from the wall and the spiral chloroplasts gradually disappear. The contents of each of the cells belonging to one filament now pass into the protuberance. The two protuberances have, by this time, formed one common tube or passage owing to the disorganisation of the wall in the middle. The contents from the cells of one filament pass through the connecting tubes into the corresponding cells of the adjoining filament and fuse with the protoplasts therein. This fusion is peculiar because the protoplast is not as usual differentiated into individual gametes. In *Spirogyra*, it is really a fusion of two protoplasts inside a cell. Nevertheless this fusion leads to the formation of a zygote and hence it may be taken for granted that *Spirogyra* shows a peculiar mode of conjugation. At the time of conjugation the appearance of the two filaments standing parallel to each other and showing a number of protuberances at intervals is like a ladder. This mode of conjugation is therefore called *scalariform* conjugation. The zygote is elliptical and shows a thick wall; it passes through a period of rest and on germination gives rise to a new filament.

Oedogonium. This also is a common fresh water alga with an unbranched filament. The base of the thread is fixed to the substratum and the basal colourless cell which shows a number of processes is somewhat specialised and should be regarded as a fixing cell. Asexual reproduction takes place commonly by means of big zoospores which are produced

singly in any cell of the filament. The zoospore is large and oval and carries numerous cilia at the narrow end. It swarms about for a time as a naked spore and then becomes fixed to a substratum by the narrow end. The cilia are lost and by repeated division a new filament is produced. This asexual

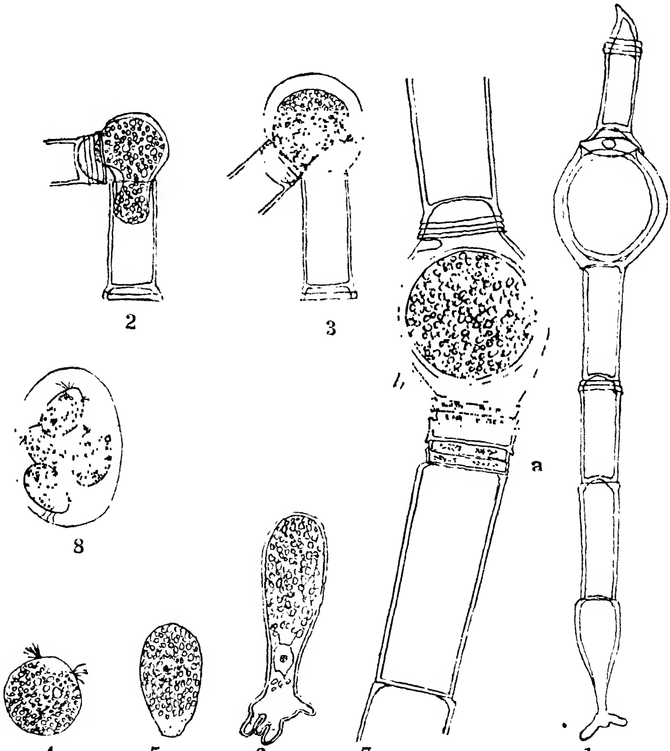


Fig. 220. Oedogonium : 1. A plant with the basal cell ; 2. and 3. Zoospore formation ; 4. Zoospore ; 5. and 6. Development of the Zoospore into a plant ; 7. A plant with sex organs : a. Antheridia, b. Oogonium ; 8. Oospore germinating. (Adapted from several sources.)

reproduction is rapidly going on so long as conditions are favourable. When conditions become unfavourable, the plant shows sexual reproduction of an advanced type. Some of the cells in the filament are specialised to produce either spermatozoids or egg. The cells that produce spermatozoids are *antheridia* and they are usually small and flat and occur close together. The cell which is to produce the egg is often

much enlarged and distinct and it is called *oogonium.* The oogonium produces only one big egg which is rich in reserve material. Two spermatozoids which are only somewhat smaller than the zoospores are produced inside each antheridial cell and on leaving the cell, they move about here and there and approach the oogonium. A special passage is developed in the oogonium and a spermatozoid manages to get in through this passage and fertilisation takes place. In *Oedogonium,* the gametes that fuse are formed in different cells and are quite different in form and behaviour. The egg is large and stationary and it does not leave the oogonium while the spermatozoids are small and motile and move towards the oogonium. The product of fertilisation, the fertilised egg or *oospore,* becomes dark and forms a thick wall. It passes through a period of rest. When it begins to germinate the protoplast divides into four naked ciliated zoospores which come out on the rupturing of the wall. Each zoospore moves for a while and then becomes fixed to the substratum. A new filament is produced in a short time by cell-division. The life-history of *oedogonium* shows an advanced type of sexual reproduction and the course of events may be indicated in outline as follows :

(a) Asexual mode. *Oedogonium*

Zoospores

Oedogonium

(b) Sexual mode. *Oedogonium*

Antheridium — Oogonium

Spermatozoids — Egg

Oospore

Zoospores

Oedogonium

Owing to the production of zoospores during the germination of the fertilised egg, the number of individuals that can be produced is increased substantially. Let us now study the algae in a general way.

Habit and Habitat. The algae are aquatic forms which occur in fresh or brackish water or even in the sea. Wherever there is moisture, some algae may be noticed as, for instance, near water-taps or on walls and trees after rains. The algae may be either free and floating or may be fixed to the substratum. The walls of cells show a tendency to become slimy in many cases and the substratum is thus made slippery.

Body. The big group of algae shows forms varying from the microscopic unicellular form to the huge seaweeds with a body differentiated into stem, rhizoids, and leaves. The majority are filamentous and consist of a number of cells with one or more chloroplasts. In addition to the chlorophyll, other pigments also develop in several forms. The simpler primitive forms may possess cilia even in the vegetative stage and are able to move about from place to place. The body does not, on the whole, show a great differentiation into tissues.

Activities. The mode of nutrition does not differ from that of a green plant. But, owing to their occurrence in water, the algae have to obtain water, salts and carbon-dioxide from the water itself and the oxygen needed for respiration is also derived from the oxygen dissolved in water. Since the body of the alga is simple, it is able to absorb water by its entire surface. The power of locomotion is shown by the primitive forms which possess cilia.

Reproduction and life-history. The algae can multiply in several ways. In the primitive unicellular forms which are found on walls and trees, the body itself divides into two which may separate and thus become two new individuals. This is merely cell-division or *fission* and the new individuals soon reach the original size. In this method, the forms are in a way immortal. Very often, in the case of filamentous forms, vegetative multiplication takes place through broken bits or fragments of the filament. A common and interesting method

is **the asexual reproduction through motile zoospores** formed **inside the cell.** On leaving the cell, these move about for a time in water, become fixed by the narrow end, lose the cilia and grow into new individuals. Such asexual reproduction is common when conditions are favourable and the advantage of motile zoospores becomes clear when you remember that the algae occur in water. The individuals which reproduce asexually through zoospores, are also producing later on gametes which may be similar or dissimilar. Fusion of

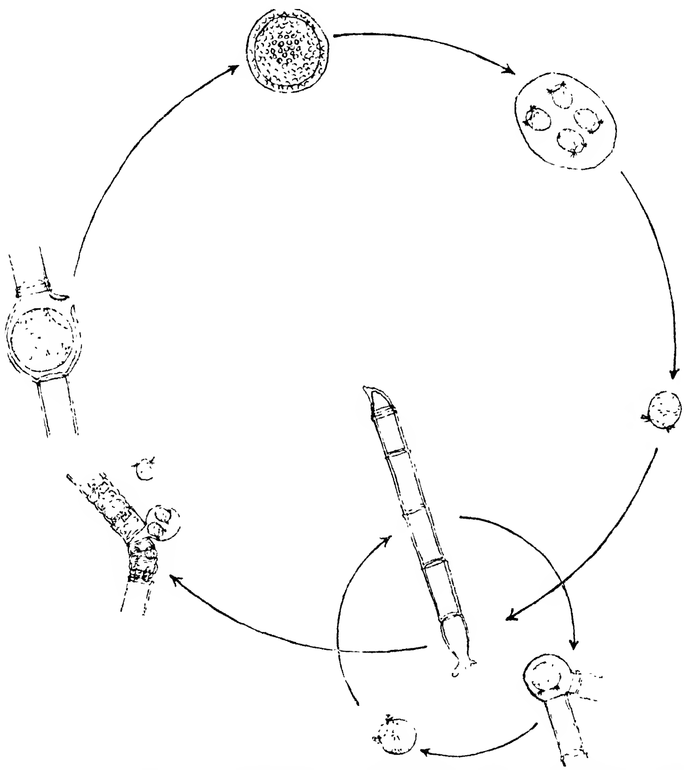


Fig. 221. Life-cycle of Oedogonium : Small circle for the asexual mode.

gametes is a common feature and it has a stimulating effect. The fusion of similar gametes which is known as conjugation results in a product called *zygote*. The gametes may be also

dissimilar and they may be differentiated into a smaller, motile form, the spermatozoid or the male gamete, and a larger, stationary form, the egg which does not leave the cell. A fusion of two such dissimilar gametes is technically called *fertilisation* and the product of fertilisation is called oospore (The term "Zygote" is also used by several botanists). Sexual union, be it conjugation or fertilisation, is noticed when conditions become unfavourable and the zygote is able to tide over the adverse season. In the higher plants like the mosses, the ferns, and the flowering plants, the asexual spore production and the sexual gamete production are occurring on different generations, one following the other. Thus the phenomenon of alternation of generations which is an interesting feature in their life-history is obvious. But in the algae like *oedogonium*, the same individual or generation reproduces itself both asexually and sexually though at different times.

The life-cycle of the algae may be generally indicated with reference to *Oedogonium* as in Fig. 221.

SUMMARY

The algae represent a lowly organised group where the body is generally very simple and undifferentiated.

They occur in water and may vary a great deal in size and form.

They absorb materials by the general surface of their body and many happen to be floating.

Multiplication may be vegetative through cell-division or fragments or asexual through zoospores. Sexual reproduction is also common and it is of the type of conjugation in primitive forms while it is of the type of fertilisation in the advanced forms.

Sexual union occurs usually when conditions are unfavourable; and the Zygote is able to tide over adverse seasons.

CHAPTER XXV

THE FUNGI

Nature. The fungi form another group of lowly organised plants which show several features of interest in their structure and life-history. One peculiar characteristic of the fungi is the absence of chloroplasts in the body, and the lack of green pigment makes a great difference in respect of nutrition. They cannot prepare complex organic carbohydrates from ordinary inorganic compounds such as water and carbon-dioxide like a green plant and are therefore compelled to lead a dependent life. They may be associated with green living plants from which they may derive organic materials. Such fungi are termed *parasites* and by their vigorous growth, they cause great damage to the host whose growth may be badly affected. There are also fungi which occur in close connection with some organic substratum like vegetables, fruits, logs of wood, and leaves embedded in the soil. These fungi are able to attack the organic matter and bring about decomposition. Some of the materials formed during decomposition are utilised by the fungi as food. Such forms as derive their materials from the dead organic substratum are known as *saprophytes* and very often the entire organic substratum is used up by the fungi. In view of the serious loss caused to man by the attack of fungi on crops and food-stuffs, the study of their structure and life-history has become very important. A few types that are common around us may be taken up before a general account is given.

The Black Mould. The Black Mould is a common fungus that occurs on moistened bread. It is seen to spread extensively on bread as a more or less white cob-web-like structure and this white thread-like tangle which forms the body is called *mycelium.* The individual branch-threads that go to make up the mycelium are known as *hyphae.* The hypha shows no cross walls in any part of the body at first and the protoplast shows numerous nuclei scattered in it. There is no chloroplast in the body. The mould secretes a

ferment which acts on the organic materials and uses them as food. It is therefore a *saprophyte* and the more rapidly

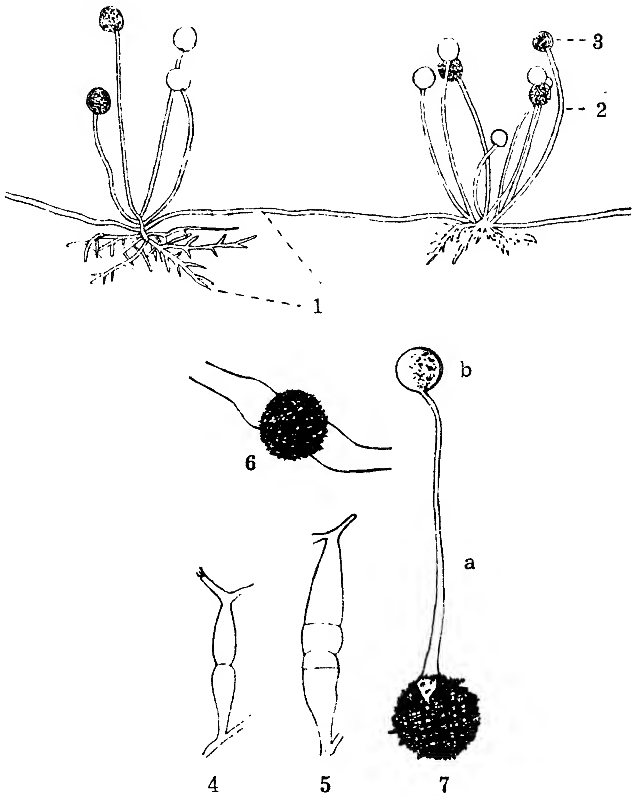


Fig. 222. The Mould : 1. Mycelium ; 2. Hyphal branch ; 3. Sporangium ; 4. Hyphae before conjugation ; 5. Later stage ; 6. Conjugation and Zygote formation ; 7. Germination of the Zygote : a. Promycelium, b. Sporangium. (Adapted from several sources.)

it grows, the more easily the organic material disappears. The mould reproduces itself asexually by means of small black particles or spores produced in sporangia. Some of the hyphal threads may be seen to grow erect and each ends in a globular sporangium. This part is rich in protoplasm and numerous nuclei are present. A small cross wall is developed at the base of the sporangium separating it from the stalk. The protoplast in the sporangium is now beginning to segment with the result that several small spores are produced inside

the sporangium. The cross wall at the base protrudes into the sporangium like a plug. When the sporangium is ripe, the spores appear black (hence the name Black Mould) and they come out when the wall of the sporangium gives way. The minute spores are carried away by wind and they are likely to fall on any exposed organic matter like bread. The spores begin to germinate and produce a new mycelium or individual. In view of the large quantity of spores produced by the mould and in view of their easy dispersal by wind, any exposed organic matter may show the black mould spreading on it. When the food-supply is running short, the mould has recourse to sexual reproduction which is a peculiar mode of conjugation. Some of the short adjoining hyphae become club-shaped, approach each other in pairs, and the free end of each is cut off by a wall as a somewhat spherical body. The two swollen ends of the pairing hyphae come into contact with each other, the wall at the point of contact is disorganised, and the contents of the two fuse to form a dark spherical zygote. This is a resting body with a thick wall and the unfavourable season is tided over. It begins to germinate some time later and the thick wall is ruptured. A short hypha protrudes which ends immediately in a sporangium inside which spores are produced. The short hypha proceeding from the germinating zygote is called *promycelium* and the development of a sporangium on this promycelium is merely a device to increase the number of individuals resulting from one zygote. Every spore inside the sporangium on the promycelium can, on leaving it, give rise to a new mycelium when it is carried by wind and deposited on organic substratum. The life-history of the Mould can be shown in outline as follows :

(a) Asexual Method.

The Mould——Spores——*The Mould.*

(b) Sexual Method.

The Mould—conjugation—zygote—promycelium and sporangium—spores—*The Mould.*

The Mushroom (*Agaricus*). This is a common fungus occurring in close contact with logs of wood in the soil. Its mycelium is thread-like and is spreading inside the substratum. What is seen outside as groups of stalked umbrella-like structures is the reproductive part. The reproductive part is more or less soft and fleshy but an examination of sections of the fleshy part shows that it is also built up of long and narrow hyphal threads which are so closely packed

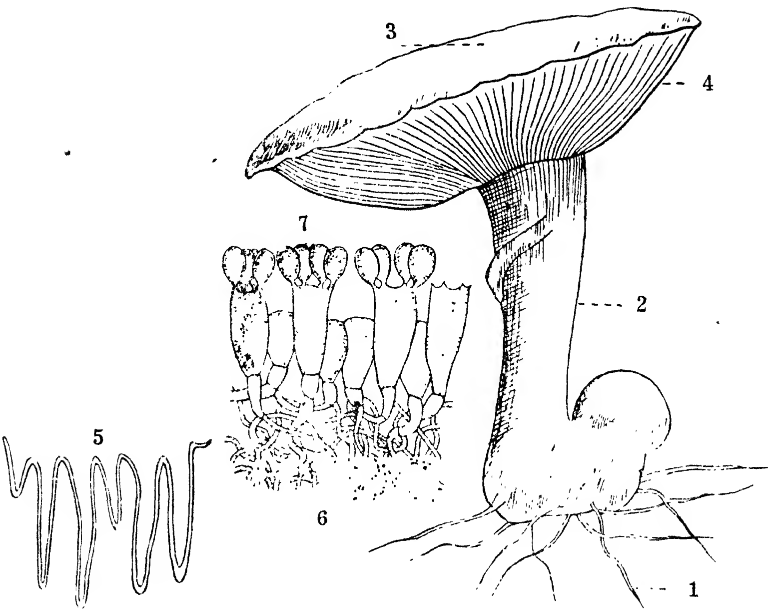


Fig. 223. Agaricus : 1. Mycelium ; 2. Stipe ; 3. Top of the Pileus ; 4. Gills ; 5. Gills protruding ; 6. A Gill dissected to show the hyphal threads ; 7. Four spores on each club-shaped body. (Adapted from several sources.)

together as to constitute a compact fleshy tissue. The reproductive part shows a lower fleshy stalk-like structure called *stipe* which carries on the top a flat umbrella, known as *pileus*. The whole structure arises as a knob-like protuberance on the mycelium and it becomes differentiated gradually into a stipe and a pileus. When the stipe elongates, the layer which enclosed the whole structure at the early stage is ruptured and left at the base. In some cases, the

remnants of another sheath may be seen on the stipe a little above the middle. The upper surface of the umbrella is smooth while the under surface shows a number of flat thin plates, called *gills,* radiating from the centre to the circumference. A section shows that each gill consists of a number of hyphal threads which curve outwards and end in club-shaped bodies (Fig. 223-6). Numerous club-shaped bodies are packed together in a layer on the surface of each gill and the free end of each club-shaped body carries towards the outside four stalked spores. When the ripe umbrella is kept for a time on a blotting paper, a number of spores will be shed on it. These spores are produced not inside a sporangium but arise as protuberances towards the outside. These are easily carried by wind and when they are deposited, say on a log of wood in the moist substratum, they germinate and give rise to a mycelium. This very soon penetrates into the wood and spreads inside. The strong log yields gradually and shows signs of decay owing to penetration by the Mushroom. In course of time the fleshy reproductive bodies make their appearance outside and the log of wood will be crumbling to powder. The Mushroom has been developing at the expense of the log of wood and is to be regarded as a saprophyte. Some forms allied to the Mushroom occur on trees and cause great damage. The Black Mould and the Mushroom are just two out of the many fungi which are of various forms. A general account of the fungi is therefore necessary.

Habit and Habitat. The fungi are lowly organised plants which are closely associated either with decaying organic substratum in dark places or with green living plants. The parasitic fungi may attack the root, the leaf, the flowers or any part of the green plant. They may be confined to one part or they may spread everywhere. Some fungi may also attack animals like insects and fishes. With the exception of a few occurring in water, **the fungi are terrestrial forms.**

Body. The body of the fungus is a tangle of branching white threads, known as mycelium. The individual threads

known as *hyphae* may be multi-cellular or may, in some cases, as in the Black Mould, show no cross walls at first. No chloroplasts are developed and hence the fungi are white though the reproductive part may, in some forms, be coloured. The mycelium may be external and be spreading on the surface of the host or substratum. In many cases the hyphal threads may penetrate inwards and send processes into the cells of the host. The body is very simple and shows no differentiation.

Activities. The fungi differ from the green plant in regard to the mode of nutrition. Owing to the absence of chlorophyll, the fungi must lead a dependent life. They are either parasitic depending on a green living plant or host; or saprophytic deriving materials from organic substratum which becomes decomposed and shows signs of decay owing to the action of the fungi. The twigs and leaves which fall on the surface of the earth decay and disappear chiefly as the result of the decomposition activity of the fungi and bacteria. The decaying organic matter is called humus and the saprophytic fungi are helpful in clearing the surface of the organic rubbish.

Reproduction. The fungi multiply easily on a large scale asexually by means of spores. The spores are produced in different ways and in different places. The spores are **often light and dry particles which are adapted for dispersal by wind.** The spores of the fungi are carried here and there in the atmosphere and organic materials which are left exposed run the risk of harbouring the spores. When the branch of a tree is cut carelessly and the surface is left exposed, the spores are likely to find a suitable lodging and to germinate. Spores are produced asexually inside sporangia in large numbers as in the Black Mould. Sometimes as in the Mushroom, the spores are produced outside and there is no sporangium at all. In several cases the hyphal thread produces by successive abstriction a number of small spores in succession. In a few cases, the mycelial threads may become split up into a cluster of spores. These spores are carried by wind and may find a suitable lodging. The parasitic fungi produce

numerous spores whose dissemination results in the rapid spread of disease. The growth of the parasite leads to the weakening of the host and in the case of our agricultural crops like the Paddy, the Cotton, the Millet, and so on, the fungal attack may lead to disastrous consequences. The wheat crop is often so seriously damaged that the loss may be terrible. In the United States, a law has to be passed which gives power to

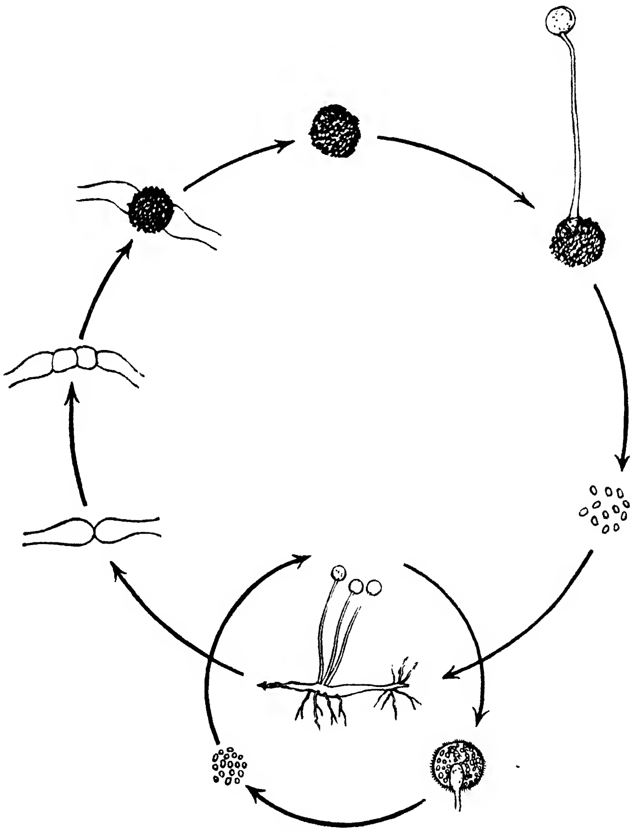


Fig. 224. Life-cycle of a Fungus (Mould): The small circle for the asexual mode.

any citizen to remove the Barberry plant from any garden since it is found to be closely associated with the life-history of a parasitic fungus attacking the Wheat plant. Sexual

reproduction has been observed in several forms and it may be conjugation or fertilisation. The details of the sex organs are not easily recognised in all forms and there are several points which still remain obscure. There is no doubt that sexual reproduction, i.e., the fusion of two gametes is also common in the fungi and this method is resorted to as in the case of the algae when conditions are not altogether favourable.

The Life-Cycle. This may be represented with reference to the black mould (Fig. 224).

SUMMARY

The fungi form a lowly organised degenerate group.

The body is a simple branched tangle of white threads, known as mycelium and the threads may sometimes be packed together to become compact and fleshy. There is no chloroplast in the cells.

The fungi are parasitic or saprophytic. The parasitic forms may be external or may penetrate into the tissues of the host.

The asexual reproduction by spores is very common. The sexual reproduction is not unknown and it occurs when conditions are unfavourable. The study of fungi is of great value since they cause considerable damage to crops, timber, and food-stuffs.

CHAPTER XXVI

THE LICHENS

Habit and Habitat. The lichens occur on bare and bleak rocks, on dry twigs, and in out of the way places where no other plant can ever have a chance. They are able to withstand great heat or cold and are not easily killed.

Body. The body of the lichen is in the form of a grey flat thallus. The thallus may be prostrate and be closely pressed to the surface; or it may have the edges raised up; or it may be a branching form fixed by one end to the substratum. The thallus is fairly thick and a section of the thallus (Fig. 225-b) reveals under the microscope the complex nature of the lichen. It is really a **compound organism consisting of a fungus and an alga closely associated together** to form apparently a single

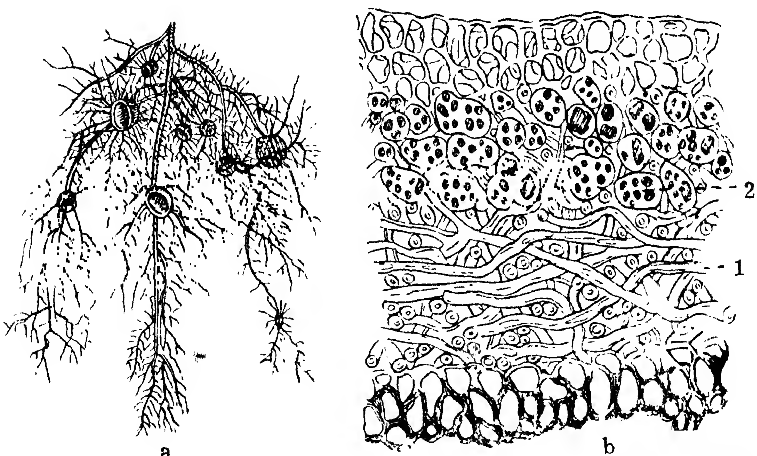


Fig. 225. Lichen : a. A branched lichen with cup-shaped reproductive bodies ; b. Thallus in section : 1. Fungal partner, 2. Algal partner. (Adapted from several sources.)

individual. The fungal portion is more prominent and the hyphal threads can be easily distinguished. The threads are rather loose in the interior but they become closely pressed

together at the surface so as to appear as compact tissue. The cells of the threads have no chloroplasts and thus reveal the fungus nature. Scattered in the interior of the thallus here and there or arranged in a definite layer, are small, green, and free cells which are clearly seen to be a form of primitive unicellular algae. These can be isolated from the thallus and made to lead an independent life. A close association of two different organisms such as we find in lichens is an interesting phenomenon known as *symbiosis* and each individual which enters into the partnership is called a *symbiont.* In a lichen, the fungus happens to be the major partner while the alga is a minor partner. However, the two individuls work together in the common interests of the organism as a whole.

Mode of Nutrition. It may appear strange that lichens are able to thrive even on open bleak rocks which will prove unsuitable for any other kind of plant. What is the special point about the lichen which enables it to get on in all inhospitable situations. The alga and the fungus are able to work together and the one is able to supply what the other wants. The microscopic alga may not, by itself, manage to get on in certain places without good protection. Nor can the fungus lead an independent life when there is no chloroplast in it. The mycelial threads of the lichen come into close contact with the rock or substratum and are able to absorb traces of water and salts from the minute crevices. The alga can count upon the fungal partner for a supply of water and salts and will also be protected against exposure by its position inside the thallus. In return, the alga will be preparing carbohydrates which will be readily available for the fungus. There is no other way in which the fungus can get the carbohydrates it needs. Thus the two organisms that go to make up the lichen are mutually helpful to each other. The symbiotic nature bears a direct relation to the nutrition of the lichen as an individual and the two different organisms "eat at the same table". This interdependence which is mutually beneficial to both is called *commensalism.*

Reproduction. A lichen can reproduce directly another lichen containing both the alga and the fungus, only in a vege-

tative manner. The thallus may split into minute bits and each of these bits which may be carried away by wind and be deposited in different places can easily develop into a new lichen under favourable conditions. There is a complex mode of spore-production which pertains to the fungal partner alone. On the thallus of the lichen may be noticed several small distinct cup-shaped bodies. These are the reproductive structures of the fungal partner of the lichen. If the cup be teased out or cut and examined under the microscope, a number of club-shaped sporangia intermingled with hairs will be seen and inside each sporangium eight biscuit-shaped spores are produced in a row. The sporangium bursts at the free end and the spores are sent out. These are carried by wind and when they reach a moist substratum they germinate and produce a small mycelium. This is only the fungus portion and it will take some time before a lichen is formed. In a moist substratum minute uni-cellular green algae are sure to be present and the mycelium is developing close by. Some of the hyphal threads can easily encircle a few algal cells. When the mycelium becomes much branched, a thallus will be formed and a few algal cells will have been caught in the interior. These algae go on dividing as is usual with the minute primitive forms of algae and through cell-division, the number of algal cells is considerably increased inside the thallus. They may be arranged here and there in no order or they may be arranged in definite layers. Now that the fungal and algal elements have become closely associated, a lichen is definitely formed. The lichens are regarded as pioneers because they can go ahead of other plants and make even areas like bare rocks habitable.

SUMMARY

The lichen is an interesting compound organism consisting of an algal partner and a fungal partner and shows symbiosis.

The symbiotic phenomenon extends to the sharing of food and hence a lichen is able to thrive even in inhospitable situations.

Vegetative reproduction consists in the separation of small bits of the thallus.

Spore-production is confined to the fungal element and the spores are produced inside the club-shaped sporangia clustered into a number of cups.

The mycelium formed during the germination of the spore comes across algal cells which become entangled and which increase in number by fission.

CHAPTER XXVII

BACTERIA

Habit and Habitat. The bacteria are the most minute among living organisms and when highly magnified, they may appear as small dots (ranging from .0005 mm. to .025 mm. in length). They occur practically everywhere; in the soil, in water, and in the atmosphere along with the particles of dust. They are found abundantly either in close association with dead organic matter or with living organisms, whether plants or animals. They are either saprophytic or parasitic.

Body. The body is simple and yet presents a variety of forms. The bacteria are unicellular with a cell-wall enclosing a protoplast. A distinct nucleus is not to be recognised and there are no plastids. Many of the bacteria possess one or more cilia with the help of which they are able to move about. Sometimes the bacteria may remain close together and look like a filament. Certain forms of bacteria are small and spherical (*Coccus* form); some are oblong or rod-shaped (*Bacillus* form); and some are spirally twisted (*Spirillum* form).

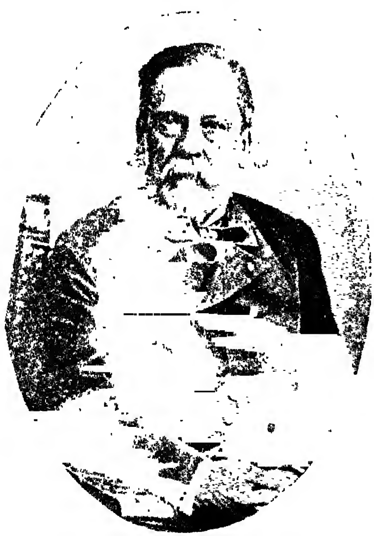


Fig. 226. Louis Pasteur (From Dr. Gager's General Botany).

Activities. So far as the mode of nutrition is concerned, the bacteria resemble the fungi and they are able to act on the complex organic materials in the substratum and derive their food from them. The saprophytic bacteria which are found in large numbers in the soil are responsible for the putrefaction of dead bodies left exposed. Many products are

formed during putrefaction and some of these are used as food by the bacteria while some escape as evil-smelling gases into the atmosphere. Much of the organic debris disappears from

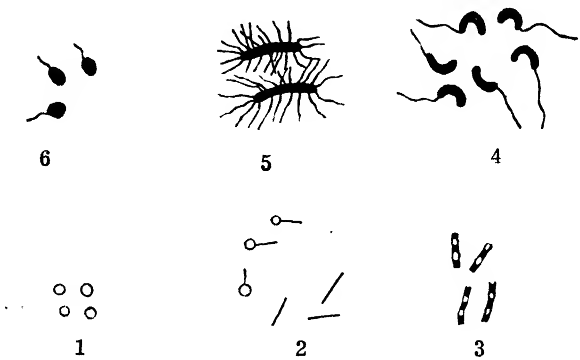


Fig. 227. Kinds of Bacteria : 1. Coccus form ; 2. Bacillus form (Tetanus disease) with spore in some ; 3. Bacillus form (Tubercle bacillus); 4. Spirillum form (Cholera); 5. Bacillus form (Typhoid); 6. Nitrifying Bacteria. (Adapted from several sources.)

the soil owing to the putrefying activity of the bacteria. The parasitic forms may be harmless in some cases but a good number of them are known to be dangerous in view of the terrible infectious diseases spread by them among human beings and other animals, such as cattle. These parasitic forms attack the tissues of the host and some of the products that are produced in the host are in the nature of poisons or *toxins* which affect the host seriously and result in its sudden collapse. As regards respiration, it is interesting to see that several bacteria can respire in the absence of free oxygen and give off carbon-dioxide. These are in most cases killed by exposure to free oxygen and are therefore to be regarded as anaerobic forms. Further, they are injured and killed by exposure to sunlight and man can prevent the outbreak of diseases like cholera in an epidemic form by carefully insisting on the sanitary principles being observed. Good ventilation and sunlight will go a great way towards preventing the outbreak of disease. Certain motile forms of bacteria sometimes come to the surface of the liquid, begin to divide and cease to move. The cell-walls tend to become mucilaginous

and the numerous individuals lie embedded in a film on the surface for a time. This condition is known as *zoogloea* stage.

Reproduction. The bacteria multiply very rapidly by cell-division and in the course of some hours they may increase by millions. The toxins produced by such an increasingly large number must necessarily tell on the host and several bacteria will escape outside along with the sputum or faeces of the host. Healthy persons who have come into contact with the diseased individual will also be affected unless proper precautions are taken; and the infection spreads quickly. The disease becomes epidemic and a number of individuals will be attacked rather suddenly. When conditions of life become unfavourable for bacteria, the protoplast within the cell recedes, becomes rounded and forms a thick wall. A **resting spore** is thus formed and it is not easily killed even by high temperature. The spores are therefore more dangerous.

Kinds of Bacteria. Bacteria may, for convenience, be considered under the following headings.

(1) *Saprophytic bacteria* which lead a saprophytic life by attacking dead organic matter, help us by getting rid of the organic debris and also making it possible for the substances in the complex organic materials to be returned to the soil in simpler forms.

(2) *Nitrifying bacteria* are doing valuable service by converting some of the ordinary substances returned to the soil into nitrates. The green plant cannot use atmospheric nitrogen and it can take nitrogen only in the form of nitrates. A supply of nitrates is maintained in nature by the activity of the bacteria belonging to this group and this group renders valuable service to the agriculturist.

(3) *Pathogenic bacteria* are the disease-producing germs which are responsible for some of the terrible diseases like Cholera, Tuberculosis, Typhoid, Influenza, and so on. The toxins affect the host and a number of bacteria escape in several ways from the host; and thus infection spreads rapidly. Humanity owes a great deal to **Louis Pasteur** who has thrown valuable light on the nature and life-history of the disease-

producing germs. He succeeded in isolating certain disease-producing germs and pointing out the close connection between certain diseases and certain forms of bacteria. By means of elaborate experiments he was able to hit upon the device of securing immunity through injection or inoculation and thus did a great deal to alleviate suffering. An interesting application of his valuable results is seen in regard to the treatment of surgical cases; and mortality which was once very high in surgical cases before Pasteur's time is considerably reduced since every modern doctor knows that he should take no ordinary care to keep off the pus-producing germs from wounds and cuts. The process of sterilising which is frequently resorted to in regard to articles of food like milk or in regard to materials used in dressing the wound is intended to kill the bacteria that may be found in a medium. We are bombarded on all sides by several kinds of pathogenic bacteria which remain invisible and there is undoubtedly great risk. But, fortunately for us, prevention and protection are possible owing to progress in the field of Bacteriology in modern times. It is the duty of every citizen to pay special attention to personal hygiene and also to do what all he can towards improving the sanitation of the city. Prevention of diseases is easily possible through better sanitary arrangements and through the cultivation of civic conscience in the community.

(4) *Nitrogen-fixing bacteria* are peculiar forms which live chiefly on the roots of *leguminous* plants and cause a number of *nodules* or *tubercles* to appear on the root. These *root-nodules* which are common in leguminous plants contain a large number of a kind of Bacterium which has got the unique power of utilising the free atmospheric nitrogen and fixing it. Complex organic nitrogenous compounds are produced by the bacteria in the nodule though the soil where the plant grows is poor and has very little nitrate. It is true that the bacteria in the nodules derive carbohydrates from the leguminous plant. But they can, in their turn, make a present of nitrogenous organic materials to the leguminous plant. The supply of nitrates is becoming a serious problem in agriculture and every time a crop is raised a large quantity of nitrates

is used up. It will be a great advantage if it be found possible to utilise the nitrogen of the air and this wonderful work can be done only by some kinds of bacteria. There is mutual

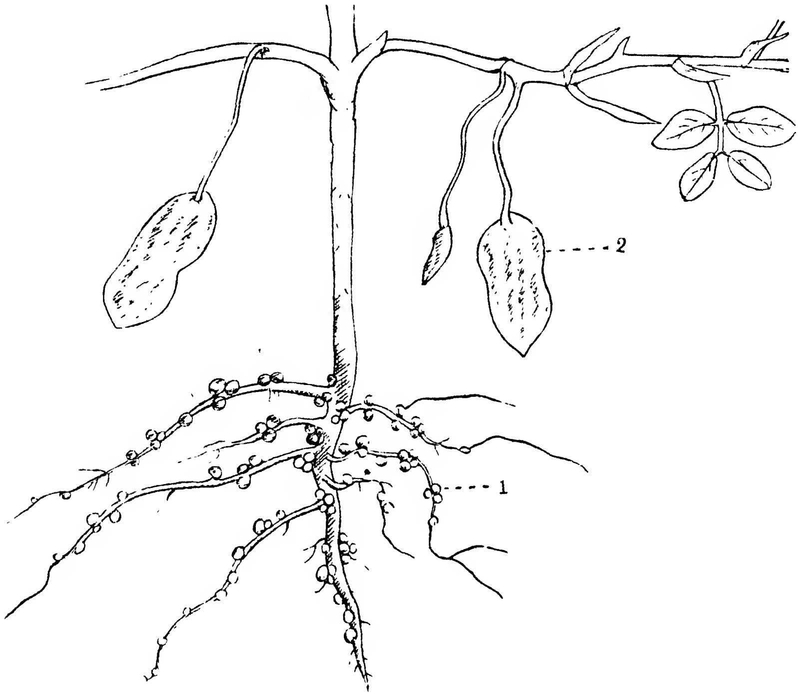


Fig. 228. The Ground-nut plant : 1. Root-nodules ; 2. Ground-nut ripening.

advantage in the case where the leguminous plant harbours the nitrogen-fixing bacteria.

SUMMARY

The bacteria are the smallest of the living organisms and are widely distributed.

Their body is simple and uni-cellular and the absence of a well-defined nucleus is noteworthy. Owing to the presence of cilia many of the forms are motile in the vegetative stage.

They have no chloroplast and are saprophytic or parasitic.

They are in most cases anaerobic and are able to bring about complex chemical changes known as putrefaction.

They multiply by fission under favourable conditions and also produce a thick-walled spore inside the cell when the medium becomes unsuitable or when conditions become unfavourable. The spores can resist a high temperature.

There are saprophytic, nitrifying, pathogenic, and nitrogen-fixing bacteria.

Louis Pasteur's services to humanity are inestimable and it is now possible to prevent outbreaks of diseases and also to secure immunity or protection against terrible infectious diseases.

CHAPTER XXVIII

PLANTS IN RELATION TO ENVIRONMENT

Problems of plants. The stationary habit has made the problems of life specially difficult for higher plants, especially the flowering plants. For instance, they have to face the problem of adaptation to the environment, the problem of protection against animals, the problem of pollination, and the problem of dispersal. You have learnt how plants have managed to solve the last two problems. But it is not enough to produce seeds and to transport them to far off places. This labour will be in vain if plants are unable to adapt themselves to the different kinds of environment in which they may be placed. Look round and you will find plants everywhere. They are seen to complete their life-cycle more or less successfully. Can the innumerable variations in the form and structure of organs prove useful to plants and enable them to get over their difficulties ?

Protection against animals. Animals, especially the cattle, cause great damage to plant-growth. Protection against animals is secured through weapons, such as thorns and spines. In scrub-jungles, shrubs are common and they are generally provided with spines which keep off the cattle. *Gymnosporia* and *Carissa* are very common in jungles and the stout thorns they possess form powerful weapons. A few plants like the Nettle carry special hairs called *stinging hairs* and they are efficient weapons. Plants like the *Arka* and *Datura* are left untouched chiefly because of the poisonous substances produced by them.

Adaptation to the environment. Conditions all over the world are by no means uniformly favourable for the growth of plants. The regions of the earth show differences in rainfall, temperature, humidity and intensity of sunlight. Differences in the nature of the soil which seriously affect the growth of plants cannot be overlooked. Plants that can do well in one area may not thrive well in quite a different region. Plants

growing under dissimilar conditions naturally show striking differences in the form and structure of organs. In nature,

Fig. 229. A plant in the dry season.

plants are seen to be well adapted to the conditions in which they occur. Have you not seen plants shedding their leaves in summer? More interesting are the adaptations of a

permanent nature suited to the environment. The vegetation of the earth falls under certain definite types and the differences in form and structure generally bear a direct relation to the environment. The vegetation in a dry area like the desert must necessarily be different from the vegetation in water. The characteristic features of some types of vegetation will now be dealt with.

Hydrophytes (*Water-plants*). Aquatic plants are found growing in tanks, pools, streams and moist places. The Lotus,

Fig. 230. Water-Lily.

the Water-Lily and the Water-hyacinth are some common aquatic plants. Water plants may be floating on the surface of water or may be submerged. Some aquatic plants like the Lotus and the Water-lily are rooted to the soil and their leaves are floating on the surface. The organs of aquatic plants do not develop much of woody tissue and there is no need for the same. Another important feature is the presence of large air-cavities which are useful for aeration. The roots are soft and do not show much of branching. In plants like the Water-Hyacinth, the petiole swells near the top

into an inflated bladder with numerous air-cavities which will help the plant to float in water. In a few aquatic plants where the tender shoot is partly aerial and partly submerged, the submerged leaves are cut up into fine green threads and thus two kinds of leaves may be seen on the same plant.

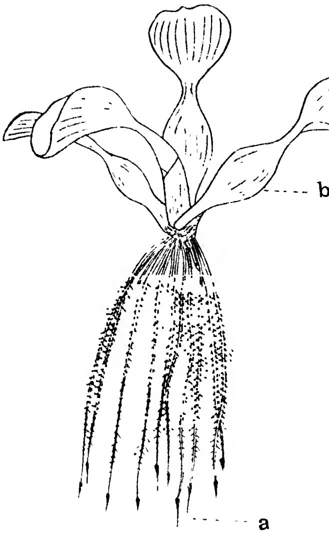


Fig. 231. The Water-Hyacinth: a. Root; b. Bladder.

Mesophytes. The vegetation in the Rain and Monsoon forests is luxuriant and commonly termed *mesophytic.* The rainfall in these regions is heavy and the atmosphere is humid. The soil is also rich and it is therefore natural that plants should be seen at their best. Huge trees with crowns of branches develop and grow to great heights. They carry large well-developed green leaves with long acuminate tips which will drain away quickly the rain water falling on them. Numerous climbers will be seen to spread over the crowns of trees and to connect the tops of different trees. The stems of twiners become woody and their cable-like stems make the interior of the forest impenetrable. On the branches of trees may often be seen a large number of different kinds of pretty flowering plants which may not be connected with the soil at all. These small plants which use the trees as a place of abode show long roots hanging in air and these roots are able to absorb rain water with the help of a spongy sheath developed at the surface. On rain-water and carbon-dioxide these small plants depend for their food and these are called *epiphytes.* In addition to these epiphytic flowering plants, there may be seen different kinds of small epiphytic ferns and mosses covering the

branches. The floor of the forest shows humus accumulating on the surface ; and several fungi and a few flowering plants make good use of this substratum and lead a saprophytic life.

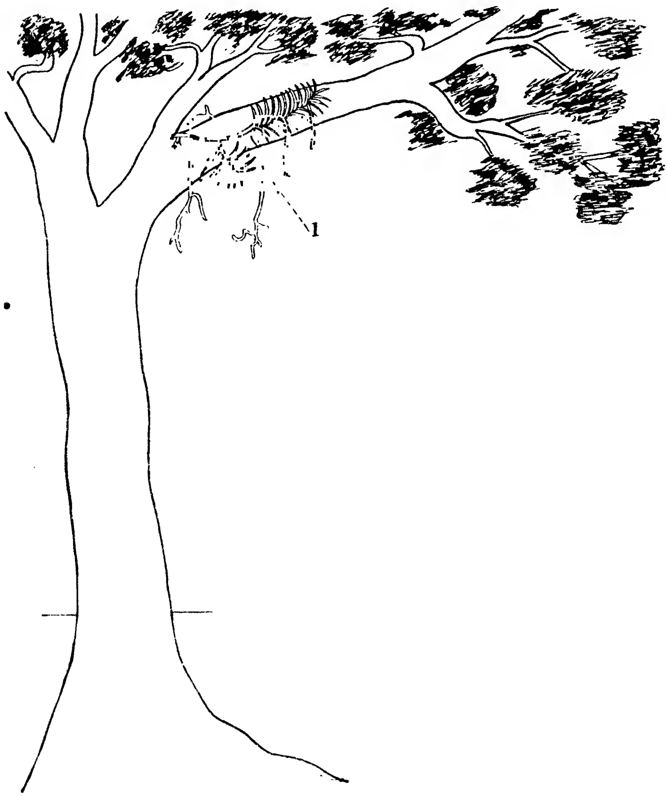


Fig. 232. Epiphyte on a tree : 1. Vanda with hanging roots.

Xerophytes or plants in dry regions. Deserts are dry sandy regions. The nature of the soil along with scanty rainfall makes the desert quite dry. Plants in dry regions have to get on with a very limited supply of water from the soil and these are known as *xerophytes.* You do not have deserts in this presidency but some of our districts can be described as dry districts chiefly because of scanty rainfall. Plants in dry regions generally show special devices to mini-

mise the loss of water due to transpiration through leaves. The type of vegetation in the ordinary dry districts is known as *scrub-jungle*. Here the vegetation is more or less open and a few thorny shrubs with crooked branches are scattered here and there. The leaves are usually small and the growth of many branches is arrested. Thus the number of leaves on the plant is reduced. Very often the small leaves are covered with a covering of hairs or a coating of wax and the epidermis

Fig. 233. Euphorbia.

is cuticularised. The stomata are fewer and may be sunk in grooves. The air-spaces in the tissues are fewer, so that water is not readily converted into vapour. Take *Casuarina*. Its leaves are reduced to minute scales and the needle-shaped green branches do not present a large surface for evaporation.

In extremely dry areas like the desert, the leaves fall away as soon as they appear and the shoot is leafless. The Prickly Pear, the Spurge (Euphorbia) and the Cactus are the typical forms common in these regions. The absence of leaves is a great advantage in the case of these plants and it is a real adaptation to dry conditions. They also show special devices

Fig. 234. Cereus (A Cactus).

for storing water in the stem which thus becomes succulent. The fleshy stem becomes green and is able to perform the assimilating function of the leaf. The Cacti are found in large numbers in the deserts of Mexico and animals trying to get at the water in the succulent stem are unable to disturb them on account of the large number of thorns on the stem. In the

case of a few plants like *Agave* (common along the Railway lines), the leaf stores up water and becomes fleshy. The sandy beach on the Coromandel coast is also a dry region and plants in this area show the characteristics of the vegetation of a dry region. The presence of common salt in the soil makes it more difficult for plants to get water. Plants on the sea-sand

Fig. 235. Opuntia (Prickly-Pear).

possess in some cases narrow or cylindrical leaves as in *Cyperus arenarius* and the transpiring area is thus reduced. The leaves frequently store up water and become fleshy as in *Launaea* and *Hydrophylax.*

Marsh plants. These plants grow in regions which are swampy. The soil is very soft. The marsh may be either a *Fresh-water swamp or a Saline swamp.* In the former case, soft grass-like plants belonging to the Cyperus type grow in groups. The latter region contains water rich in common salt and this water is not suitable for the growth of plants. Hence this area is termed *physiologically dry,* and plants growing in saline regions are technically known as *Halophytes.* The supply of water becomes a difficult problem in the case of

plants growing in this region and they show some of the features of the vegetation in the sea-sand or in deserts. The leaves

Fig. 236. Agave.

are generally succulent and narrow. The marshes are water-logged and in some plants (*Avicennia*) the root-system produces special roots known as *breathing roots* which grow up against gravity and project beyond the surface of water. They show large air-cavities and are able to take part in the exchange of gases. Marsh plants may also produce stout aerial roots which reach the soil. These roots form good supports to the plant and appear as stilts as in *Pandanus*. The advantage of vivipary which is noticed in the Mangroves has been already pointed out.

CHAPTER XXIX

ORIGIN OF NEW FORMS

Resemblance. You have already seen how plants can be classified into groups subordinate to a group according to the resemblance that is noticed among them. The resemblance is very close in certain cases while it may be very remote between certain forms. What is the meaning of this resemblance ? Is it accidental or can it tell us anything about living things ? If we should think of this phenomenon of resemblance alongside of differences, we should begin to ask ourselves how living things have come to be what they are to-day. There are two common theories which seek to give an explanation to this great question.

The theory of creation. One view which was commonly held for a long time is that the different forms of living things that one finds to-day have been created as such in the distant past. This view implies that the living forms have been unchanging or immutable through all the ages and this impression will be strengthened if one be guided by the apparent constancy of forms of plants and animals within one's own memory. On this theory of creation, the resemblance that is noticed among the different kinds of plants and animals can have no meaning or significance. The different kinds of Paddy or Wheat or Plantain should, each of them, be presumed to have been created as such and one kind of Paddy is no more related to another kind than it may be to a Mango plant. This view of constancy or immutability of organic forms is not justified since plants and animals tell a different tale.

The theory of evolution. A later theory which is accepted by all is the one commonly known as *evolution.* This theory implies that living forms are not really unchanging and that the forms found in existence to-day are the modified descend-

ants of forms that had lived in the past ages. That the present living forms are descended from those that lived in the past geological ages may appear a simple idea to-day but it should be admitted that it is a great conception. If the forms of to-day be the modified descendants of the past, the resemblances noticed among them come to have a meaning and they should be regarded as indicating real blood-relationship. The theory of Evolution supposes that simple organic forms which were in existence in the past, produced descendants which became gradually modified or changed in different ways owing to various causes. We owe this great idea to the patient and prolonged study of two great thinkers, **Charles Darwin** and **Alfred Russel Wallace.** The likelihood of change was in a way suggested by some earlier biologists but the credit of establishing the idea of mutability as a natural and universal feature belongs to the two great men mentioned above. They arrived at the same conclusion independently; but, from the beginning, the name of Charles Darwin whose reputation for careful observation and patient investigation was very high, came to be associated with the **theory of organic evolution.** He was able to prove conclusively that the organic forms had been changing as the result of the operation of several factors. The idea of evolution or change is accepted by all but there is difference of opinion with regard to the manner in which the change may have been brought about. Charles Darwin made it quite clear that **his theory did not attempt to explain the origin of life.** How life originated will perhaps remain a great mystery! **Darwin's theory should be understood as a bold attempt at explaining how living things have come to be what they are to-day.**

Fig. 237. Charles Darwin (From Dr. Gager's General Botany).

Darwinism. Darwin was struck with two principles in living forms. Firstly, parents tend to produce offspring more or less resembling themselves. This tendency is universal and is commonly known as *heredity.* It is a conservative principle which compels the offspring to conform to the type as far as possible. Side by side with this hereditary principle, there is also noticed quite a different principle, namely, *variation.* No two individuals are ever seen to be exactly alike though they are descended from the same parents. Variation is regarded by Darwin as a widely occurring phenomenon and every part of the individual including the physical and mental characters may show variations from the type in different directions. The variation may be in respect of quality or quantity and in several cases a variation in one part may induce by correlation a number of variations in other systems. Thus variation should be treated as a deviation and it may arise in any way. It is not every variation that can be transmitted to the off-spring. Such of the numerous variations as are transmissible are very valuable because they form the materials for evolution. How can a new form be expected to arise when the transmissible variations occur ? It is at this point that the original contribution of Darwin (popularly known as **Darwinism)** helps us. He was carefully observing the practice of breeders and horticulturists who were able to place in the market new forms of animals and plants respectively. Just think of the different kinds of the Pigeon you often see in the aviary. Compare the wild forms of plants with their cultivated forms, such as the Cabbage, the Wheat, the Paddy, and the Sugarcane. The several cultivated forms differ from one another and also appear different even from the wild type in each case and the difference is astonishing. Darwin saw that the breeders succeeded in their efforts through a process of rigorous and careful selection which he called *Artificial selection.* The breeder is always on the look-out for any chance variation that may happen to appear in the animals under his care. **It is true he cannot create variations ; but he is quick to notice them as they occur.** When he thinks a particular variation note-

worthy, he selects those individuals showing this variation and allows these forms alone to breed. The other individuals

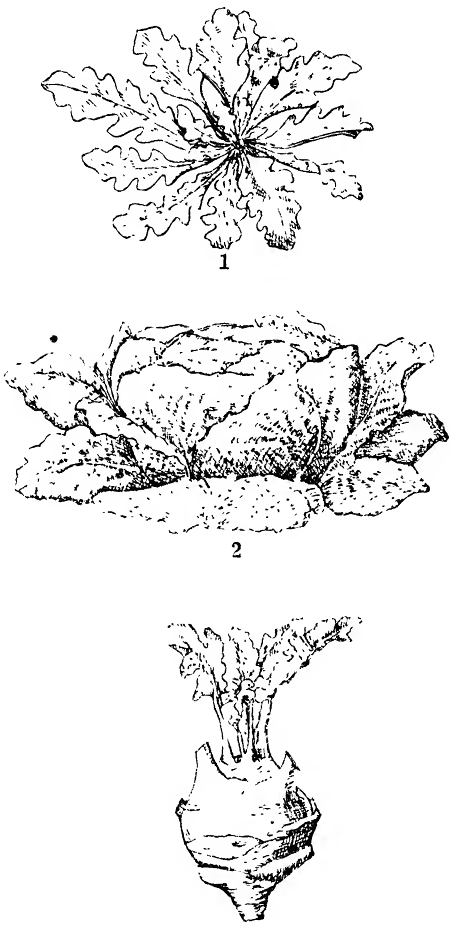


Fig. 238. Wild and cultivated forms : 1. Wild form of the Cabbage plant ; 2. The cultivated Cabbage ; 3. The cultivated Kohlrabi.
(Adapted from several sources.)

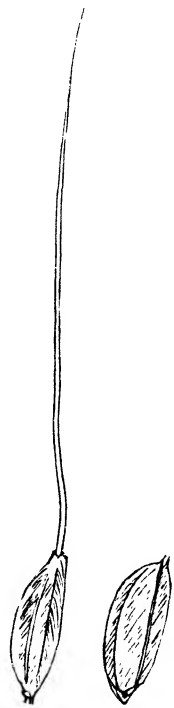


Fig. 239. The Paddy : 1. A wild form ; 2. A cultivated form.

are of no interest to him for the present and if the variation should happen to be of the transmissible type, the offspring may certainly show this variation more distinctly. Such of the

offspring as show the variation in a still more marked degree are again selected and thus through a rigorous and careful selection, a new form is finally produced. The new form has diverged from the original stock very much though the change has been proceeding step by step, gradually and imperceptibly.

Darwin asked himself whether a similar process of selection could be imagined to occur in nature. In nature, there is a keen struggle for existence owing to the rapid rate of multiplication ; and competition is keen between allied forms in regard to space, food, light and so on. This keen struggle is a matter of life and death and it is natural that this struggle for existence should prove to be a process of selection. Forms which are better fitted will survive while forms that are not fit will have no chance of continuing to exist and producing descendants. In such a struggle, the variations that arise naturally may in several cases prove useful and give an advantage to the individuals. Forms which show such useful variations will enjoy an advantage over others and may be expected to survive. Thus, as the result of such a continued selection in nature called *Natural selection* by Darwin, the old form which has begun to vary in a useful direction will be slowly changing further and further and in course of time will become modified into a new species. The new form or species is thus the product of natural selection which has utilised the variations to a definite purpose. The idea of Natural selection caught the imagination of thinkers and the evolution of organic forms was accepted in spite of opposition at the outset. Darwin asks us to bear in mind that Natural selection can have a far wider scope than artificial selection. It can operate on all the individuals scattered in different habitats and at all stages in their life-history and throughout all geological ages. Thus, according to Darwin, the origin of new forms should be attributed to the three factors, *viz.,* **Heredity, Variation and Natural selection.** Whatever difference of opinion there may be with regard to Darwinism i.e., the power of Natural selection, scientists are agreed that animals and plants have been evolving and that the old simpler forms had given rise to the present highly differen-

tiated complex forms. **Darwin's own words would give** a clear idea of the history of living things through all the geological ages: "The affinities of all the beings of the same class have been represented by a great tree. The green and budding twigs may represent species, and those produced during former years may represent the long succession of extinct species . . . Of the many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear the other branches; so with the species which lived during long-past geological periods, very few have left living and modified descendants. . . . As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever-branching and beautiful ramifications."

Evidence of Evolution. Charles Darwin has taken pains to explain that the theory of evolution rests on strong evidence. He points to the unmistakable anatomical evidence found in "the similar frame-work of bones in the hand of a man, wing of a bat and leg of the horse." Think again of the vascular tissue in the higher plants and of the general similarity in its structure. The evidence from the study of the embryos of animals belonging to different groups is also interesting and he asks what the significance of the similarity in the embryos of different groups of animals can be in regard to certain features. There is a third class of evidence based on what are called *fossils*. Various kinds of remains of animals and plants that lived in the past are lying embedded in the crust of the earth and, day after day, interesting remains are being discovered. Sometimes the entire animal might have been entombed in ice as in the case of the big elephant-like animal, Mammoth, and such an entombed animal is spoken of as a fossil.

There are other ways in which ancient organic forms or parts of organic forms can be preserved as fossils. If you

observe a river after a heavy rain, you will notice the muddy nature of the water in the river. All kinds of substances forming the " flotsam and jetsam " are carried and the muddy nature of the water is due to the large quantity of rock-material carried by the river. The surface of rock is undergoing constantly a process of change or *weathering* owing to the action of the sun and water. The rock becomes split up and the minute particles are carried away by wind. The bigger pieces are rolled down the mountain stream when it rains and they may be broken further and rounded into pebbles. The river carries a considerable quantity of fine rock material to the sea or the lake and there it settles as sediment. The sediment accumulates slowly and becomes hardened in course of time into a rock under water owing to pressure. Because this rock is formed under water through the slow accumulation of sediment, it is known as the sedimentary rock which shows the characteristic form of layers. Many of the huge mountains like the Himalayas had been formed under water in the sea in this manner and then lifted up. The sediment is at first soft and rich in mineral matter. Parts of animals and plants carried by the river or growing in the shallow water will be covered with the sediment and will have a chance of being preserved in the hard rock.

Our earth is supposed to be several millions of years old. Its crust is usually divided according to the nature of the rock into three periods or eras, namely, (1) the *Palaeozoic* or old era, (2) the *Mesozoic* or secondary era, and (3) the *Cainozoic* or modern era. Evidence of the existence of organic forms before the Palaeozoic age is very scanty and even in the earlier portion of the Palaeozoic age, only simple and primitive forms of plants could have existed. It was in the later portion of the Palaeozoic that the ferns and their allies seemed to have become prominent. A few primitive flowering plants had begun to appear even in this period but they were generally indistinguishable from the ferns. The secondary period was the age of flowering plants while the fern group had dwindled. The old giants of the fern group had disappeared and their remnants could be seen in the form

of coal. In the modern period the higher flowering plants, the Angiosperms, have come to occupy a dominant position.

The crust of the earth where traces of the past forms of animals and plants happen to be preserved as fossils throws light on the history of organic forms. Forms which possessed hard parts like bones or wood were naturally preserved in the rock easily. Impressions of leaves left in the soft mud which hardened into rock later on are very common and they should also be treated as fossils. Sometimes, trunks and twigs of trees are seen preserved as hard fossils. These were formed by the incrustation of the sediment round the trunk or twig in the first instance. The sediment round the trunk hardened into rock and retained the general form of the trunk or twig even after the trunk had disappeared. Such a fossil is known as *cast*. Another wonderful method of preservation is through the replacement of the material in the organic structure particle by particle by the rapid infiltration of mineral matter contained in the rich sediment. When the organic matter is thus completely replaced by the mineral matter, the fossil will become a hard and stony body and this mode of preservation is called *petrifaction*. Such petrified fossils show in several cases the details of internal structure; and with the help of these specimens great palaeontologists have found it possible to explain the relation between the different groups of plants such as the Fern and the Flowering plant. One fact stands out clearly from a study of the fossils. It is found that the ancient forms were different from the existing forms in several respects. But at the same time the points of agreement are many and unmistakable. Does it not mean that the present forms are the modified descendants of older forms? Fortunately for biology, it has been found possible to trace with certainty on the evidence of fossils the evolution of certain animals such as the modern horse and the elephant. In some of the celebrated museums in England, Germany, and America valuable fossil forms which have been discovered as the result of patient exploration are kept on show. Evidence from various sources points to the soundness of the view that

organic beings have been changing and that an evolution has been going on. For the past three decades, investigators have been studying intensely the problems of variation and heredity in the laboratory and the main position established by Darwin regarding the evolution of forms has not yet been shaken though important modifications have to be made in certain respects.

Mutation. Darwin's idea was that small minute variations which might even escape notice, would form the materials for natural selection. These minute infinitesimal variations are, according to Darwin, worked up gradually generation after generation until, after a lapse of a long time, an altogether new form is produced. The new form will thus be evolved step by step through intermediate stages. **Hugo de Vries**, a famous Dutch Botanist, had occasion to observe one peculiar phenomenon. From out of the seeds of a plant called *Oenothera* he got a few individuals which happened to differ remarkably in regard to certain features. The variations were definite and distinct from the beginning and it seemed to him that they arose all on a sudden at one step and not gradually. Such sudden variations which arise at one step abruptly as distinct forms are called *mutations* and de Vries holds the view that new forms frequently arise suddenly as mutations. How the variation itself arises was not explained satisfactorily by him.

Fig. 240. Hugo de Vries (From Dr. Gager's General Botany).

Mendelism. **Gregor Mendel** was an Austrian monk who was deeply interested in carrying on experiments with plants so as to find out the laws governing heredity. He was the con-

temporary of Charles Darwin and the results of his experiments were marvellous. It so happened that his work remained unnoticed in the general controversy regarding Darwinism. In the beginning of the twentieth century, a few eminent investigators were able to discover his work and were struck with the remarkable accuracy of his results. Mendel took varieties of the Pea plant which differed obviously in one or more pairs of contrasting characters and studied the problem of heredity experimentally by crossing two such varieties. He studied one pair of characters at a time. He was careful to keep the individuals belonging to each generation strictly apart and also to count the number of individuals in each generation showing the particular character. The procedure which he adopted helped him to formulate a few fundamental laws relating to heredity. It is not possible to deal with his experiments in this book but it may be stated that his experimental method is being largely followed to-day in several biological laboratories. His experiments show that every individual may be regarded from the point of view of heredity as a group of characters and that the germ-cells contain some factor in them which is in some way responsible for each character. The several characters behave in the majority of cases as independent units and all kinds of chance combinations seem to be possible at the time of fertilisation. The distribution of characters is not unlike the shuffling and dealing of the playing cards **and the likelihood of a new form making its appearance through a new combination becomes plain.** This possibility of getting new combinations is of immense practical importance

Fig. 241. Gregor Mendel (From Dr. Gager's General Botany).

and attempts have been successfully made to produce new types by crossing two varieties. Improved varieties of Paddy, Millet, Sugarcane and other crops are now possible (as in the Agricultural Institute, Coimbatore) and some hold the view that the Mendelian procedure forms a ready and easy means of obtaining new forms. It cannot be denied that Mendel has placed in the hands of the breeder and the horticulturist a scientific method which is bound to contribute to the prosperity of the human race.

Views regarding the factors that brought about a change in organic forms may differ. The change may have come about as the result of natural selection acting on the infinitesimal variations as pointed out by Charles Darwin. It may be that mutations of the kind mentioned by Hugo de Vries may have served as the starting point of new forms. There is also the work of Mendel before us which points out clearly the likelihood of new types arising through crossing or *hybridisation.* Whatever may be the method, **the fact remains that organic forms have been constantly changing and that evolution has been going on.** Variations that make new forms possible occur of their own accord in the germ substance and the effect of natural selection is clearly seen in the harmonious adaptation to the environment noticed in the successful forms of plants and animals. Evolution is, on the whole, a progress from simple primitive types to complex advanced forms.

APPENDIX A.

SELECT QUESTIONS FROM THE PAPERS SET FOR THE INTERMEDIATE EXAMINATIONS OF MADRAS, ANNAMALAI AND ANDHRA UNIVERSITIES.

1. Describe, with sketches, the germination of the Date Seed or of the Coconut.

2. Describe the various modifications of the Underground Stem. How do they differ from the roots?

3. Explain, with examples, the following terms:—Apocarpous; Syngenesious; Pulvinus; Stipel; and Pepo.

4. Explain, with diagrams, the following:—Aggregate fruit; Helicoid cyme; Prickles; Cladode; and Loculicidal.

5. Give an account of the different ways in which weak-stemmed plants grow and point out in each case how their habit of growth is useful to them.

6. Describe clearly the different parts of a Papilionaceous flower, and point out how its structure may be useful in bringing about cross-pollination.

7. Explain what is meant by homologous organs. Illustrate your answer with examples that you have studied.

8. Describe with the help of diagrams the germination of (a) Castor and (b) any one of the following:—Date, Coconut, or Palmyra.

9. Give an account of the different modifications of the stem and explain how they are useful to the plant.

10. Enumerate the different agencies concerned in the dispersal of fruits and seeds, stating how they operate in each case.

11. Explain the morphological nature of the edible parts of the following:—Coconut; Cashewnut; Orange; Pomegranate; Potato; Sweet-potato.

12. Give an account of the climbing plants and show how they differ from the epiphytes.

13. State the characters of the family Malvaceae. Draw a diagram of the vertical section of the flower of any plant of this family and name the parts. What product of great economic importance is derived from a plant of this family? Explain the nature and place of origin of this product.

14. Describe the characteristics of the following:—(a) The Pistil of Labiatae; (b) The shoot (vegetative part only) of the Plantain and (c) The flower of Papilionaceae.

15. Describe the chief characteristics of the Palmae, and explain briefly the economic importance of the family.

16. Mention the chief characteristics of Myrtaceae. Draw diagrams to show the different parts of the flower of any plant belonging to it.

17. Draw a diagram of the median longitudinal section of a papilionaceous flower. Explain how cross-pollination is brought about in the flower.

18. Describe the chief characteristics of the Rubiaceae. Name three plants of economic interest and mention the name of the economic products derived from each and the parts of plants yielding them.

19. Give an account of the chief characteristics of the Euphorbiaceae, and describe any two types of flowers found in the family. Mention three plants of economic importance known to you, stating the economic products derived from each and the parts of the plant yielding them.

20. Describe, with suitable sketches, any one plant belonging to the family Acanthaceae.

21. Describe with diagrams any one plant belonging to the Musaceae.

22. How will you proceed to demonstrate the path taken by water in the plant-body? Explain clearly what happens to the water absorbed from the soil.

23. What is meant by Transpiration and what purpose does it serve?

24. Give an account of the chief functions of the green leaves of plants.

25. What are the materials that a plant obtains from the soil? Show by means of an experiment how the materials are taken into the plant.

26. Describe any experiments you have seen or made to show that light is necessary for the formation of starch.

27. Describe the different ways by which plants bring their leaves into positions where they can best perform their functions.

28. Describe some simple experiments to show that (1) carbon-dioxide and (2) Sunlight are necessary for photo-synthesis.

29. Describe an experiment to show the process of respiration in plants.

30. Of what use is light to the plant?

31. What do you understand by carbon assimilation? State the conditions under which it can take place.

32. Explain the behaviour of different organs of plants to gravity.

33. Explain the following phenomena:—(a) Growth of moulds on stale bread during the rains; (b) Growth of mushrooms on decaying matter; (c) Souring of milk.

34. What do you understand by Catabolism? Would you call respiration a catabolic process? What is its significance to the plant?

35. What is root-pressure? Explain its cause. Describe an experiment to demonstrate it.

36. Describe the phenomenon of alternation of generations with special reference to the life-history of a fern.

37. What are lichens? In what respects do they differ from the algae and the fungi.

38. Compare and contrast the mode of nourishment in the sporophytes of a moss and a fern.

39. Give an account of the different parts of a fully grown fern and compare it with a moss.

40. Compare the life-history of any fungus you have studied with that of an alga.

41. Write a detailed account of any fungus that you have studied.

42. Compare the gametophyte of a fern with that of a Moss.

43. Describe the vascular bundle of the stem of any dicotyledon and explain the functions of the different tissues composing it.

44. Explain with sketches the internal structure of the root of a dicotyledon which has undergone secondary thickening.

45. Describe the structure of a young dicotyledonous stem, and explain the functions of the different parts.

46. Describe the structure and mechanism of the stoma and explain the physiological importance of the stomata.

47. Describe with the help of suitable diagrams the anatomy of a leaf and explain how its structure is suited to the work it performs.

48. What are inter-cellular spaces? Where are they found and in what ways are they useful to the plant?

49. What are lenticels and where do they occur? Explain their structure and function.

50. Describe the distinguishing features of anemophilous flowers and contrast them with those of entomophilous ones.

51. Write an account of vegetative reproduction in flowering plants, giving examples.

APPENDIX B.

HERBARIUM.

Students will not be slow to realise the value of excursions in connection with the study of plants. It will be good if their experience in the laboratory be combined with that in the field. In these days of "go-as-you-please" facilities, it would be a pity if students do not show an inclination to go out on excursions in twos and threes and observe plants in their natural surroundings. The study of plants in the field is at once good and useful and the satisfaction they will derive by pursuing it as a hobby throughout their life will be undoubtedly great. They may turn to good account their observations and what they require as outfit for the purpose is negligible. A *magnifying lens,* a small light tin box or *vasculum* for the collection of specimens and a few *mounted needles* will not cost much. The *dissecting microscope* will be convenient for examining the parts easily in the laboratory. They will do well to make on the spot a careful note in a pocket book of the chief points of interest regarding (1) the habit and habitat of the plant and (2) the influence of the season and the soil on the growth of plants. Eminent botanists speak highly of the value of collecting plants and preserving them for study and reference. A good collection of plants which are well preserved and kept is known as a *Herbarium* and it will always have a value of its own.

You may like to know how plants can be preserved. Specimens should be collected as fresh as possible in the field and put immediately in the collection box to prevent them from exposure to the sun. In the case of small herbs, the entire plant should be pulled up. In the case of shrubs and trees, it will be enough if a few good shoots with flowers and fruits be collected. As soon as you return home, you should take steps to preserve them without delay. You should have in stock for this purpose a good supply of sheets of blotting paper (20″ × 16″); and if you do not have sufficient quantity of blotting paper, you can use along with it old newspapers. A specimen is taken out from the collection box and spread out on the blotting sheet; and care should be taken to see that the leaves of the specimen are not crowded together. A few sheets of blotting paper or newspaper should be placed over it; and a second specimen is taken and spread out on the same. Thus specimens are taken out one after another and laid flat on sheets. This pile of specimens is kept in a place free from moisture and a heavy weight is placed on the top of the pile. The specimens will be pressed closely to the drying sheets and the moisture in them will be gradually absorbed. The object in using the blotting paper is to let the moisture in plants be absorbed gradually so that the specimen

may keep its form. Next day the pressed specimens should be gently removed one after another from the sheets and spread out on fresh dry sheets while the sheets used the previous day may be exposed to the sun to get dry. You will be surprised to see the large quantity of water absorbed from specimens by the drying paper. The changing of sheets should be done at least once each day to prevent the collection from becoming mouldy. In the course of a few days many of the specimens with their leaves will become dry and be ready for mounting which will enable you to handle them easily. Plain and slightly thick sheets of white paper of a uniform size are needed for this purpose and a specimen is fixed to the mounting paper by using small slips of gummed paper here and there. It is usual to poison the specimen before mounting it so as to prevent fungal and insect attacks. Alcoholic solution of corrosive sublimate * may be sprayed over the specimens and this treatment is necessary to preserve them in good condition. The mounted sheet should show the name of the specimen and of the family to which it belongs, the name of the collector, the date of collection and the name of the locality. Details regarding the locality and date of collection are very necessary and identification of specimens is done with the help of a Flora containing short descriptions of plants arranged under the respective families. The flora of the Presidency of Madras, an excellent work begun by Mr. J. S. Gamble, is a very useful series which can be consulted with great advantage. There is also the Flora of British India by Sir J. Hooker, a monumental work. In the course of identification of the specimens preserved in the herbarium, it is likely that certain specimens may appear new and raise problems. By correspondence with well-established herbaria maintained in different countries, the point can be decided and you will have done something by making your own contribution to the sum-total of knowledge. The mounted sheets showing the species of the same genus are placed together inside a folded coarse brown paper and the entire collection is kept in a suitable herbarium cabinet. The value of the herbarium will depend upon the care taken in collecting specimens from different localities, preserving them carefully, and arranging them systematically according to a widely-accepted system of classification.

* * * * *

* Prof. Oliver's instruction in the First Book of Indian Botany (Page 327) may be followed :—The preservative solution may consist of corrosive sublimate dissolved in spirits of wine, in the proportion of two drachms to the pint. It is very poisonous, and should be kept labelled, and used with care.

APPENDIX C.

SELECT BOOKS FOR STUDY OR REFERENCE.

1. Text-Book of Botany by E. Strasburger and others.
2. Text-Book of Botany, Vols. I and II, by J. M. Coulter and others.
3. Botany of the Living Plant by F. O. Bower.
4. General Botany by C. S. Gager.
5. A Text-Book of General Botany by W. H. Brown.
6. A Text-Book of General Botany by Holman and Robbins.
7. Principles of Botany by J. Y. Bergen and B. M. Davis.
8. Botany: Principles and Problems by E. W. Sinnott.
9. The Natural History of Plants by Kerner-Oliver.
10. Structural Botany by Asa Gray.
11. Structural Botany, Parts I and II by D. H. Scott.
12. Introduction to Plant Geography by M. E. Hardy.
13. First Book of Botany by F. Oliver.
14. The Nature and Work of Plants by D. T. MacDougal.
15. Experiments with plants by W. J. V. Osterhout.
16. Practical Plant Physiology by F. Keeble.
17. Vegetable Physiology by J. Reynolds Green.
18. Plant Physiology by W. F. Ganong.
19. Plant Physiology and Ecology by F. E. Clements.
20. Elements of Plant Biology by A. C. Tansley.
21. Elementary Biology: Plants by J. E. Peabody and A. E. Hunt.
22. Elementary Studies of Botany by J. M. Coulter.
23. Plant-life on Land by F. O. Bower.
24. Links with the past in the plant world by A. C. Seward.
25. Plant Life and its Romance by F. E. Weiss.
26. Living Creatures by C. Von. Wyss.
27. Botany of To-Day by G. F. Scott Elliot.
28. The Life of the Plant by C. A. Timariazeff.
29. Plant Life by F. B. Farmer.

INDEX

NOTE: *Plain numbers stand for page numbers.*
Bold numbers stand for figure numbers.

I.B.—45

D

E

P

T